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Vol. 92. Part 2. Pp. 285–456,* 1 pl. 28th December, 1942

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THE TRANSACTIONS OF THE ROYAL ENTOMOLOGICAL SOCIETY OF LONDON

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LONDON:
PUBLISHED BY THE SOCIETY AND
SOLD AT ITS ROOMS, 41, QUEEN'S GATE, S.W.7

Price £3 0s. 0d.

* *With title-page, contents and index.*

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ON THE CLASSIFICATION OF THE LARVAE OF THE VESPIDAE (HYMENOPTERA)

By J. A. Reid, A.R.C.S., B.Sc.

Manuscript received i.x.1941.

Read i.iv.1942.

With 137 Text-figures.

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Introduction and Acknowledgements, with a List of the Species Considered.

This work has been carried on in the department of Entomology of the Imperial College of Science and Technology under the direction of Dr. O. W. Richards, and I wish to acknowledge my indebtedness to him for the indispensable advice and guidance which he has given me.[1]

The purpose of this work was to attempt to show whether or not it is possible to construct tables for the identification of the larvae of the diplopterous wasps of the family Vespidae; and incidentally to describe and figure a number of species of Vespid larvae so far undescribed, and to note any evidence concerning the relationships, one to another, of the various groups within the family Vespidae.

A list of the species dealt with in the text is given below. Those marked with an asterisk (*) are species of which only figures and descriptions have been examined; the remainder are those of which I have had specimens, and of these, all but the specimens of *Vespa crabro* L., and *Vespula vulgaris* (L.), were collected by Dr. Richards in British Guiana in 1937.

[1] In the present circumstances it has not been possible to communicate with authors resident abroad and it is therefore necessary to express here an acknowledgement to them for the use of certain figures which have been redrawn for this paper.

EUMENINAE.

Odynerus Latreille.

* *labiatus* Haliday.
* *humeralis* Haliday.
* *vespiformis* Haliday.
* *scabriusculus* Spinola.
* *subpetiolatus* Saussure.
* *molinae* Saussure.

Subgenus *Hoplopus*.

* *laevipes* Shuckard.
* *spinipes* (L.).
* *poecilus* Saussure.

Subgenus *Ancistrocerus*.

* *parietum* (L.).
* *oviventris* Wesmael.

Subgenus *Microdynerus*.

* *nugdunensis* Saussure.

Rhygchium Spinola.

* *oculatum* (Fabricius).

Alastor Lepeletier.

* *atropos* Lepeletier.

Eumenes Latreille.

* *unguiculata* (Villers).
* *arbustorum* (Panzer).
* *pomiformis* (Fabricius).

VESPINAE.

Vespula Thomson.

vulgaris (L.).
* *germanica* (Fabricius).
* *rufa* (L.).
* *norwegica norwegica* (Fabricius).

Vespa L.

crabro L.

POLISTINAE.

Polistes Latreille.

carnifex (Fabricius).
crinitus Felton var. *multicolor* (Olivier).
canadensis (L.) var. *cinctus* Lepeletier.
* *foederatus* Kohl.
* *gallicus* (L.).

POLYBIINAE.

Polybia Lepeletier.

catillifex Moebius.
bistriata (Fabricius).
rejecta (Fabricius).
micans Ducke.

Protopolybia Ducke.

minutissima (Spinola).
sedula (Saussure).

Stelopolybia Ducke.

infernalis (Saussure).

Nectarinia Shuckard.

scutellaris (Fabricius).
* *lecheguana* (Latreille).

Metapolybia Ducke.

cingulata (Fabricius).

Mischocyttarus Saussure.

lecointei (Ducke).
carbonarius (Saussure).
injucundus (Saussure).
collarellus Richards.
superus Richards.
metoecus Richards.
oecothrix Richards.
synoecus Richards.
cerberus Ducke var. *acheron* Richards.
M. sp. 10.
surinamensis (Saussure).

Apoica Lepeletier.

* *pallida* (Olivier).

Synoeca Saussure.

* sp.

Belonogaster Saussure.

* sp.

ZETHINAE.

Zethus Fabricius.

* *dicomboda* (Spinola).

Discoelius Latreille.

* *merula* Curtis.

The present paper is only an attempt to show whether or not it is feasible to make keys for the identification of the larvae of the VESPIDAE, and the keys given were constructed for this purpose. The number of species examined is so comparatively small that nearly all the conclusions are tentative. When summarising the characters of a genus or subfamily, the characters are placed in what seems to be the order of importance, the first few being the more important and usually the diagnostic ones.

EXTERNAL MORPHOLOGY OF A TYPICAL VESPID LARVA.

The larvae of the VESPIDAE are nearly all much alike in general appearance, being soft, entirely apodous grubs with few striking characters; this makes it necessary to examine the finer structure of the head, when searching for means to classify them. The body comprises a head with simple mouth-parts, three thoracic segments and ten abdominal ones. There are ten pairs of spiracles. The head capsule is roughly circular in outline when viewed from in front, and about twice as wide, from side to side, as it is deep from front to back; it may be brown and partially sclerotised or colourless and almost as soft as the body integument. There are a number of structures upon the head capsule which can usually be seen, at least after staining and mounting (see fig. 20).

The epicranial suture :—this is only visible in its entirety upon some of the more sclerotised heads, such as those of species of *Vespa*; it is shaped like an inverted Y.

The stem of the Y, or median suture, can usually be seen, at least near the top of the head, and runs from the back of the head capsule to a point about half-way down the head, where it forks into the two frontal sutures, which terminate in the upper margin of the clypeus. The area enclosed between these two frontal sutures and the clypeus is the frons. The lower border of the clypeus is formed by its junction with the labrum which depends from it; the width of the clypeus is about equal to the distance between the bases of the mandibles. Most often the only clypeal sutures clearly to be seen are the clypeo-labral and the lateral ones, up to the point where the latter run into the anterior tentorial pits, as they usually do. The anterior tentorial pits are small deep depressions, always visible in stained preparations; they are the points at which the tentorium is attached (see fig. 51).

The antennae are very simple in structure, being circular areas, apparently thinner than the surrounding parts of the head capsule and marked out by a thickened peripheral ring of cuticle. Each antenna bears three minute sensillae and each of these is in the form of a tiny circle with a minute raised point in the middle. The position of the antennae is as shown in fig. 1. The temporal bands always occupy the positions shown in fig. 1 and are areas differentiated from the rest of the head capsule in much the same way as are the antennae; their function, if any, is unknown, but they are not confined to Vespid larvae, being present upon the heads of many other Aculeate larvae, though apparently not on those of the honey bee. This is unfortunate, for the anatomy of this larva has been fully described by Nelson (1924). Kirmayer (1909) in his study of *Vespula vulgaris* (L.) merely refers to them as temporal bands.

The mouth-parts consist of the mandibles, which are attached to the head capsule, and the labial and maxillary lobes. The mandibles fit into emarginations of the head capsule at each lower corner of the latter, and are moved by muscles attached to a pair of apodemes, which project from the base of each mandible into the head. The maxillae are a pair of soft lobes, continuous with, and situated on, either side of the labium. Each maxilla bears a pair of conical papillae. On top of each papilla is a variable number of small sensillae, similar to those in the antennary rings. The relationship between these papillae and the structures of the adult maxillae is still a little uncertain. Grandi (1935 : 39) interprets the more external papilla as homologous with the adult maxillary palp, and the more internal one as homologous with the external lobe (galea) of the adult maxilla. For the sake of simplicity the noncommittal term papilla will be used in this work. The labium consists chiefly of the roughly circular mental lobe, centrally placed; the area between the foot of this lobe and the thorax may perhaps be regarded as the submentum. The mentum bears a pair of papillae similar to those upon the maxillae; behind these papillae, that is nearer the mouth, is a transverse slit which is the opening of the salivary gland. Between each labial papilla and the opening of the salivary gland, there is usually a single sensory bristle (see fig. 22), though there are several in the Polistinae and in the Eumeninae apparently there is none.

The sense organs of the head are mostly simple sensory bristles, each articulated basally to a small circular area of membrane. These bristles are constantly present upon the labium, the maxillae, and the labrum, and occur also upon the head capsule, where they are subject to great variation in numbers and size from species to species. In addition, upon the upper surface of the labrum and upon the lower surface or palate, another kind of sensory structure occurs; these are small rounded papillae and upon the summit of each is borne a single minute short sensilla or else a sensory bristle; the sensilla or bristle is articulated as already described. These sensillae are referred to in the text as conical sensillae.

The sensory bristles together with the antennae, and possibly the temporal bands, appear to complete the sensory equipment of the head capsule. Certain small pits or punctations, which can sometimes be seen upon the head capsule in certain fixed positions, mark the attachment of muscles, which are probably concerned with the working of the pharynx; these punctations assume the form of large smoothly rounded depressions, in such genera as *Polybia* which have unsclerotised head capsules.

The thorax occupies from an eighth to a quarter of the total length of the body, and is composed of the usual three segments; the third segment is the widest. There are two thoracic spiracles, situated between the pro- and meso- and the meso- and meta-thoracic segments, but the segmentation of the thorax on either side, at the level of the spiracles, is not very clear. In the full-grown larva, upon the ventral thoracic surface there can often be seen ten small circular areas, more transparent than the rest of the integument, each one marking the position of a wing or limb bud underneath.

The abdomen, consisting of ten segments, makes up about four-fifths of the bulk of the body. It tapers posteriorly, the first segment being commonly the widest one of the body. Spiracles are borne in the mid-lateral line on the first eight segments, towards the anterior edge of each segment. The anus is a transverse opening upon the tenth segment, the shape of this segment varying considerably. There is a variable number of protuberances upon the abdominal and thoracic segments; when fully developed they consist of a dorsal series and

a lateral series. The dorsal series is composed of low transverse ridges in the middle of each abdominal segment, close on either side of the mid-dorsal line, strongest on segment I of the abdomen and usually not discernible on segment VIII and IX. The lateral series is formed of low circular humps in the middle of each segment, forming a line below the spiracles; weakly developed on the meso- and meta-thorax, strongest on segment I of the abdomen and diminishing in size posteriorly. These protuberances appear to be bare of the tiny sensory bristles which are sparsely scattered over the body cuticle, and also of the closely set microscopic denticles, with which the cuticle is normally covered. It has been conjectured that the protuberances may perhaps help to keep the larvae of the social forms in their cells, but this does not explain why the larvae of the EUMENINAE also possess them.

KEY TO THE SUBFAMILIES EXAMINED.

The following table for separating the subfamilies dealt with I feel to be trustworthy so far as it goes, but no doubt an examination of species belonging to some of the other subfamilies, such as the ZETHINAE or ROPALIDIINAE, would necessitate modifying it. Complete lists of the characters discovered for each subfamily will be found in the appropriate sections farther on; only the more diagnostic characters are employed in the key.

Table for the determination of the subfamilies EUMENINAE, VESPINAE, POLISTINAE, and POLYBIINAE.

1(4). All the lower margin of the clypeus is clearly ventral to a line drawn between the points of insertion of the mandibles into the head capsule.

2(3). The extreme width of the labrum is as great as, or greater than, the width of the clypeus where this joins the labrum. The distance between an antenna and the base of the nearest mandible is *less* than the distance from the mid-point on the anterior edge of the labrum to a line drawn between the bases of the mandibles . . EUMENINAE.

3(2). The extreme width of the labrum is always less than the width of the clypeus where this joins the labrum. The distance between an antenna and the base of the nearest mandible is *greater* than the distance from the mid-point on the anterior edge of the labrum to a line drawn between the bases of the mandibles . . . . . VESPINAE.

4(1). At least the median point of the lower margin of the clypeus is dorsal to a line drawn between the points of insertion of the mandibles into the head capsule.

5(6). With a group of several sensory bristles behind each labial papilla. The maxillary lobes prominent and almost spherical . . . . POLISTINAE.

6(5). With only one sensory bristle behind each labial papilla. The maxillary lobes not more prominent than usual and not nearly spherical POLYBIINAE.

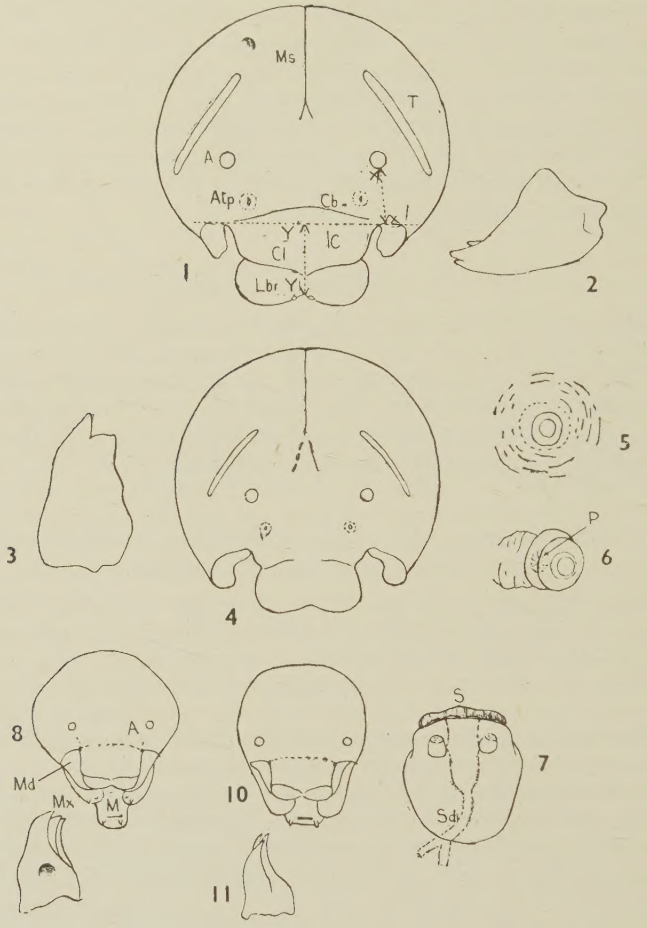
EUMENINAE.

No larvae of this subfamily were available, so that conclusions regarding the larval characters are based only on the examination of drawings and descriptions; these were of 17 species of EUMENINAE, by G. Grandi, L. Micheli and F. Claude-Joseph.

Attention has been confined to discovering possible subfamily characters, and no attempt has been made to separate the genera dealt with.

Characters of the subfamily Eumeninae.

The ventral margin of the clypeus, from which the labrum depends, is ventral to the level of the bases of the mandibles.



Figs. 1–11.—*Rhygchium oculatum.* 1, Front view of head capsule. A, antenna: Atp, anterior tentorial pit: C, clypeus: Cb, upper margin of clypeus: Cl, lower margin of clypeus: Lbr, labrum: Ms, median suture: XX and YY, see p. 290: T, temporal band; 2, Mandible; outer ventral view; 3–7. *Eumenes unguiculata.* 3, Mandible; outer dorsal view; 4, Head capsule; 5, Spiracle; surface view, showing concentric markings on the cuticle; 6, Spiracle and part of trachea, dissected out. P, processes guarding opening of the trachea; 7, Mentum. S, striate ridge of opening of salivary gland: Sd, duct of salivary gland. Figs. 1–7 adapted from Grandi. 8–9. *Odynerus spinipes.* 8, Head. A, antenna: M, mentum: Md, mandible: Mx, maxilla; 9, Mandible. Side view; 10–11. *O. oviventris.* 10, Head; 11, Mandible; side view. Figs. 8–11 adapted from Micheli.

The maximum width of the labrum is greater than, or not less than, the width of the clypeus where this joins the labrum.

The distance between an antenna and the base of the nearest mandible is *less* than the distance from the mid-point on the anterior edge of the labrum, to a line drawn between the bases of the mandibles (see fig. 1 XX and YY).

In those figures in which it is shown, the dorsal margin of the clypeus is ventral to, or occasionally (*Eumenes unguiculata* Villers) level with, the anterior tentorial pits. (This can be seen in 6 out of the 9 species of which figures have been examined.)

The palate always bears numerous coarse spinous processes, distinct from any sensillae that may be present (fig. 17).

The following characters are also present in varying degrees of constancy :—

It seems from examination of the figures, that the single sensory bristle (many in the species of *Polistes*), which is always found in the other subfamilies directly behind each labial papilla, between the papilla and the opening of the salivary gland, is missing in this subfamily. Possibly the bristles are very small and have been overlooked, but that this has happened in every species figured is unlikely. There is a clear drawing of the labium of *Eumenes arbustorum* Panzer by Soika (see fig. 16) in which the bristles are exactly represented, but there is no indication of one behind the labial papilla.

The anterior tentorial pits occupy positions nearer the median vertical line of the head than do the antennae. These pits are shown only in Grandi's figures. At one time I thought that the position of the anterior tentorial pits, whether they were medial to, or lateral to the antennae, would prove a valuable character, but in all except the species of *Polistes* these pits are medial to the antennae or directly below them. In the species of *Polistes* they are immediately below or slightly lateral to the antennae. This character may prove valuable when material of the other subfamilies is examined.

The mandibles, as the figures show, are all of the same type, being stout, somewhat angular in cross section, and usually with three apical teeth of about equal size.

There are sclerotised patches of cuticle upon the palate in which conical sensillae, as previously described, occur (fig. 17). Occasionally (*Odynerus nugdunensis* Saussure) the cuticle seems to be unsclerotised, though the sensillae are present.

The spiracles illustrated by Grandi for *Eumenes unguiculata* Villers (see figs. 5 and 6) appear to be typical of the subfamily. In *E. unguiculata* a comparatively small spiracular opening gives access to an almost spherical atrium, which communicates with the trachea by a smallish opening, guarded by a ring of projecting processes, while on the cuticle around the peritreme is a pattern of semi-complete concentric circles.

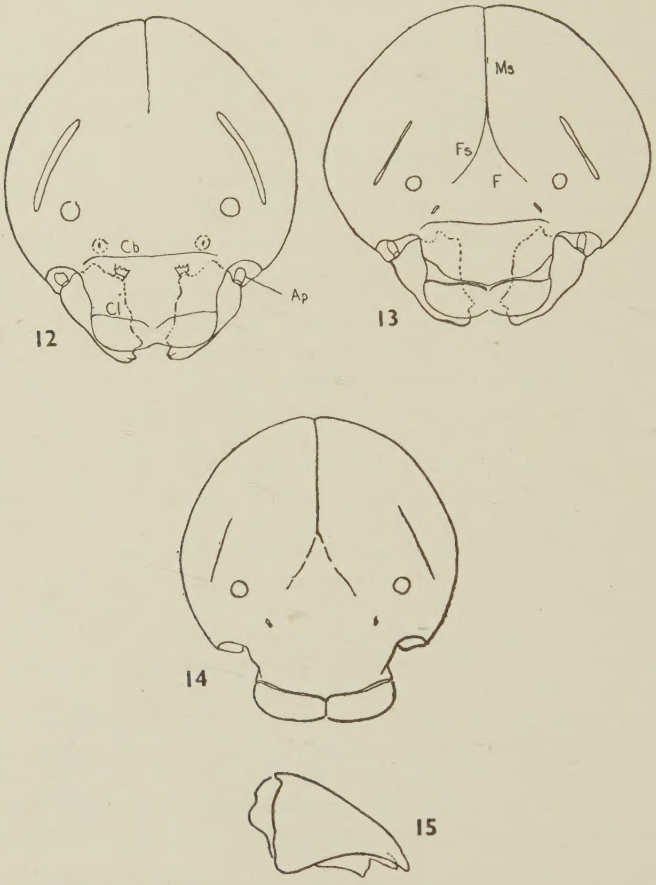
Upon the mentum there is frequently a transverse ridge in association with the opening of the salivary gland, and in some species this ridge is shown as vertically striate : *Eumenes unguiculata* Villers (fig. 7), *Ancistrocerus oviventris* (Wesmael) and *Odynerus spinipes* (L.).

Sometimes the ventral margin of the clypeus tends to overhang the base of the labrum, especially medially : *E. unguiculata*, *E. arbustorum* Panzer, *Odynerus nugdunensis* Saussure (fig. 18).

The labrum is divided by a median longitudinal groove into two lateral lobes, which are considerably swollen. This character is not confined to the EUMENINAE, but appears to be very marked in this subfamily. There is a further point about the labrum which seems to be rather characteristic of this subfamily; the posterior margin is usually strongly biarcuate, the bottom of the emargination often nearly meeting the corresponding emargination in the anterior border of the labrum (see fig. 18). There is an area of membrane between the posterior margin of the labrum and the anterior border of the clypeus, so that one should beware of supposing that the anterior border of the clypeus is of the same shape as the posterior margin of the labrum; some of the figures examined convey this impression. Frequently the palate also is bounded posteriorly by a similar biarcuate margin (fig. 17).

The figures and descriptions of *Eumenes unguiculata*, *E. arbustorum*, *E. pomiformis* Fabricius, and *Odynerus nugdunensis* by Soika, and those of *Eumenes pomiformis*, by Grandi and *Odynerus laevipes* Shuckard, by Micheli, were not

examined until some months after the subfamily characters had been decided upon from examination of the figures and descriptions of the other species. Thus it is satisfactory to be able to record that these further species served only to confirm the characters already deduced. Claude-Joseph (1930) gave figures of the heads of the larvae of six species of *Odynerus* from Chile. The figures are small and without much detail, but are fairly clearly of the Eumenine type, as



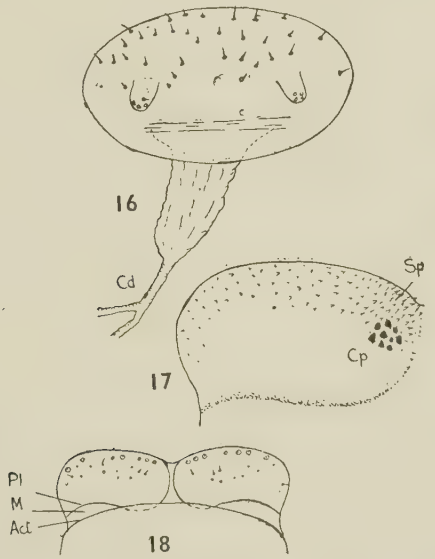
Figs. 12–15.—12, *Odynerus parietum*. Head capsule and mandibles. Ap, apodemes of mandibles: Cb, upper margin of clypeus: Cl, lower margin of clypeus; 13, *O. poecilus*. Head capsule and mandibles. F, frons: Fs, frontal suture: Ms, median suture; 14–15. *Alastor atropos*. 14, Head capsule; 15, Mandible; seen ventrally. Figs. 12–15 adapted from Grandi.

they all show the prominent clypeus and labrum; the former descending below the bases of the mandibles. The biarcuate posterior margin of the labrum is to be seen in all the figures, and the mandibles are apparently of the normal type for the subfamily, being stout and often bluntly tridentate; the apical third of each, heavily sclerotised and dark in colour.

He figured the following six species: *Odynerus labiatus* Haliday, *O. humeralis* Haliday, *O. vespiformis* Haliday, *O. scabriusculus* Spinola, *O. subpetiolatus* Saussure, *O. molinae* Saussure.

The following is a list of the other species of which descriptions have been examined.

Species.	Described by
Eumenes unguiculata (Villers).	Grandi (1934). Giordano Soika (1933)
E. arbustorum (Panzer).	Giordano Soika (1933).
E. pomiformis (Fabricius).	Grandi (1930). Giordano Soika (1933)
Odynerus (*Hoplopus*) *laevipes* Shuckard.	Micheli (1934).
O. (*H.*) *spinipes* (L.).	Micheli (1930).
O. (*H.*) *poecilus* Saussure.	Grandi (1937).
O. (*Ancistrocerus*) *parietum* (L.).	Grandi (1937).
O. (*A.*) *oviventris* Wesmael.	Micheli (1930).
O. (*Microdynerus*) *nugdunensis* Saussure.	Giordano Soika (1934).
Rhygchium (or *Rhynchium*) *oculatum* (Fabricius).	Grandi (1937).
Alastor atropos Lepeletier.	Grandi (1935).



Figs. 16–18.—16, *Eumenes arbustorum.* Mentum; viewed proximally from above. Note no bristle between either of the papillae and the opening of the salivary gland, O. Cd, common duct of salivary glands; 17, *E. unguiculata.* One side of the palate. Cp, sclerotised patch with sensillae: Sp, spinous processes; 18, *Odynerus nugdunensis.* Labrum. Acl, anterior margin of clypeus: M, membrane between clypeus and labrum: Pl, biarcuate posterior margin of labrum. Figs. 16–18 adapted from Soika.

Vespinae.

The available material of this subfamily was very limited, consisting of the larvae of *Vespula vulgaris* (L.), and the dried remnants of three larvae of *Vespa crabro* L., recovered from an old nest. In addition, figures and descrip-

tions of *Vespula norwegica norwegica* (Fabricius) and *Vespula rufa* (L.) by Grandi and of *Vespula germanica* (Fabricius) by Giordano Soika, were examined.

Characters of the subfamily.

The lower margin of the clypeus is ventral to the level of the bases of the mandibles.

The labrum is nowhere as wide as the clypeus where the latter joins the labrum.

The distance between an antenna and the base of the nearest mandible is *greater* than the distance from the midpoint on the anterior edge of the labrum, to a line drawn between the bases of the mandibles.

The upper margin of the clypeus extends dorsally beyond the level of the anterior tentorial pits.

The walls of the spiracular atria bear branched or unbranched spines directed radially inwards.

There are sclerotised patches upon the palate, bearing conical sensillae; the patches are arranged roughly symmetrically upon either side of the median longitudinal line of the palate.

The mandibles are stout, angular in cross section, and terminate commonly in three obtuse teeth.

There is one sensory bristle behind each labial papilla.

The anterior tentorial pits are medial to the antennae.

Grandi shows a transverse ridge upon the labium of *Vespula rufa* (L.) similar to the ridge commonly present upon the labium in the EUMENINAE. Sometimes the palate bears spinous processes, *Vespula vulgaris* (fig. 24) and *Vespula germanica*, but these are very much smaller and less numerous than in the EUMENINAE and are only visible with the high power of a microscope. The ventral margin of the clypeus tends to overhang the base of the labrum. The posterior margin of the palate is often well defined.

Vespula Thomson.[2]

One species examined at first hand.

Vespula vulgaris (L.).

In this description, as in those which follow, only points which are not covered by the general description of a Vespid larva, given earlier, will be mentioned; for instance, the number of pairs of spiracles is always ten; this has been stated in the general description and will not be repeated for each species described.

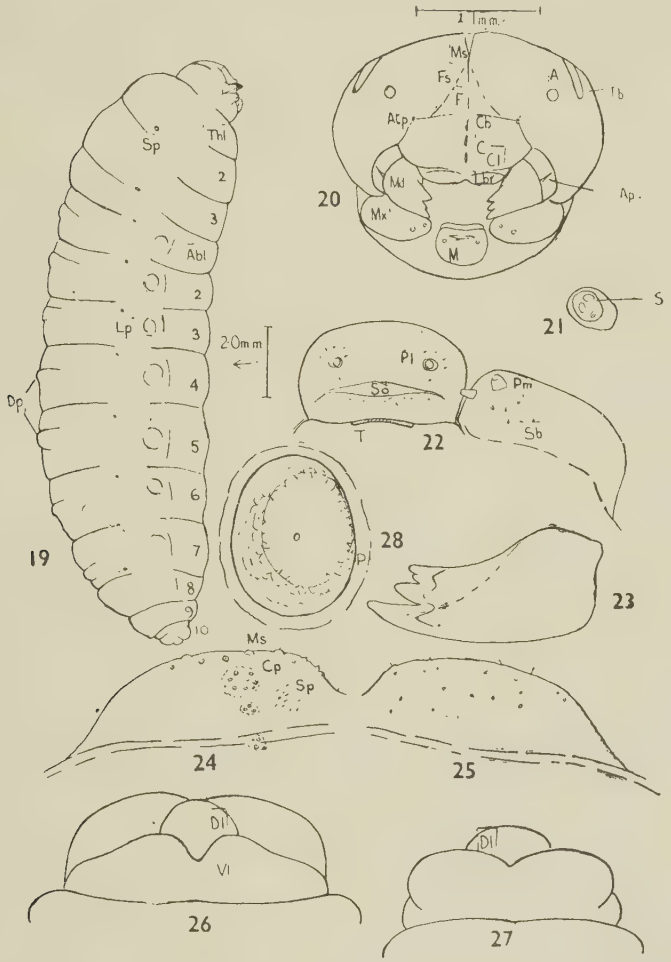
The mature larva is about 12·0–18·0 mm. long.

Head (see fig. 20): The head capsule is firm and hairless, the temporal bands are ferruginous, and the frons and clypeus are pale brown. The antennae and the maxillary and labial papillae appear as brown rings. The mandibles are stout, recalling those described for the EUMENINAE; the terminal third of each shades from pale brown to deep brown upon the teeth, of which there are three, the dorsal one slightly bifid.

The sutures of the head are well marked. The anterior tentorial pits are considerably medial to the antennae. The labrum is rather small and is sharply notched medially on its anterior border; it bears only few bristles and conical sensillae. The palate bears some

[2] Duncan's (1939) description of the larva of *Vespula pennsylvannica* (Saussure) was seen too late for inclusion in the present paper.

sclerotised patches in which are sensillae, as described in the EUMENINAE, and on each side of the median line there is a patch of small spinous processes (fig. 24).



FIGS. 19–28.—*Vespula vulgaris.* 19, Side view of larva. Ab, 1–10, abdominal segments: Dp, dorsal protuberance: Sp, spiracle: Lp, lateral protuberance: Th, 1–3, thoracic segments; 20, Head front view. A, antenna: Ap, apodeme of mandible: Atp, anterior tentorial pit: C, clypeus: Cb, upper margin of clypeus: Cl, lower margin of clypeus: F, frons: Fs, frontal suture: Lbr, labrum: M, mentum: Md, mandible: Ms, median suture: Mx, maxilla: Tb, temporal band; 21, Papilla of mentum much magnified. S, sensilla; 22, Mentum and maxilla, viewed from above. Pl, labial (mental) papilla: Pm, maxillary papilla: Sb, sensory bristles: So, opening of salivary gland: T, sclerotised transverse bar, part of internal skeleton of head; 23, Mandible, viewed from in front; 24, Half of palate (ventral surface of labrum). Cp, sclerotised patch with sensillae: Ms, conical sensilla: Sp, spinous processes; 25, Half of labrum; 26, Anal segment, ventral view. Dl, dorsal lip of anus: Vl, ventral lip of anus; 27, Anal segment, dorsal view. Dl, dorsal lip of anus; 28, Spiracle. P, peritreme: O, opening of trachea.

The maxillae and labrum are firm, and bristle sensillae are sparse. There is one sensory bristle behind each labial papilla.

Body: the body is hairless and the cuticle colourless, both the usual conditions among Vespid larvae. Dorsal protuberances are developed on abdominal segments I–VIII and lateral ones on abdominal segments II–IX. The ventral lip of the anus is bifid, and the dorsal half of abdominal segment X is rather prominent laterally. The spiracles appear as brownish spots under the binocular microscope; the atrium of each spiracle contains numerous small points on its walls projecting into the lumen of the cavity (fig. 28).

Vespula germanica (Fabricius).

Described and figured by Soika (1934).

Head. This differs from that of *V. vulgaris* (L.) only in the following respects. The head is described as colourless. The labial papillae bear four sensillae each, as against the three of *V. vulgaris*. There seem to be more sensory bristles upon the labium and maxillae, and the distribution and numbers of the sensillae upon the palate and labrum is somewhat different; but the positions and numbers of the sensillae upon the head capsule and mouth-parts of Vespid larvae, are in general very variable, so that the differences cited above probably have little significance. The mandibles are similar to those of *V. vulgaris*. The body is not described nor are the spiracles; the processes in the latter might yield a good means of separating the two species.

Vespula norwegica norwegica (Fabricius).

Described and figured by Grandi (1934).

This species differs from the preceding only in the following respects :—

Head (fig. 32): The head capsule is much broader than that of *Vespula vulgaris* (L.). The lateral margins of the clypeus apparently do not run into the anterior tentorial pits as is normally the case. The labrum bears rather more sensillae and is gently emarginate, instead of sharply notched. Apically the mandibles bear only one tooth, which is ventral, and the rest of the apical margin is serrate.

Body. The dorso-lateral prominences on the last abdominal segment, mentioned in the preceding species, are here very well developed (figs. 33 and 34). The spiracles are conspicuous and bear complex branched spines on the walls of the atria (fig. 35). The two thoracic spiracles are smaller than the first abdominal one.

Vespula rufa (L.).

Figured by Grandi (1935).

Grandi does not describe this larva and only gives two drawings of the head, so that one cannot tell whether the body would have shown any characters of value; one would have liked to know the shape of the processes in the atria of the spiracles, if they exist.

Head (fig. 29): This appears to be the same as in the two preceding species, except in the following respects. The upper margin of the clypeus is not shown; there is a bulge in the outline of the head capsule at the level of the antennae and there are a few spines on the outer faces of the mandibles. These last two characters might be specific. The shape of the mandibles is very similar to those of *Vespula vulgaris* (L.). The figures show a strongly developed ridge or spinneret upon the mentum; this also might be a character of specific importance (figs. 30, 31).

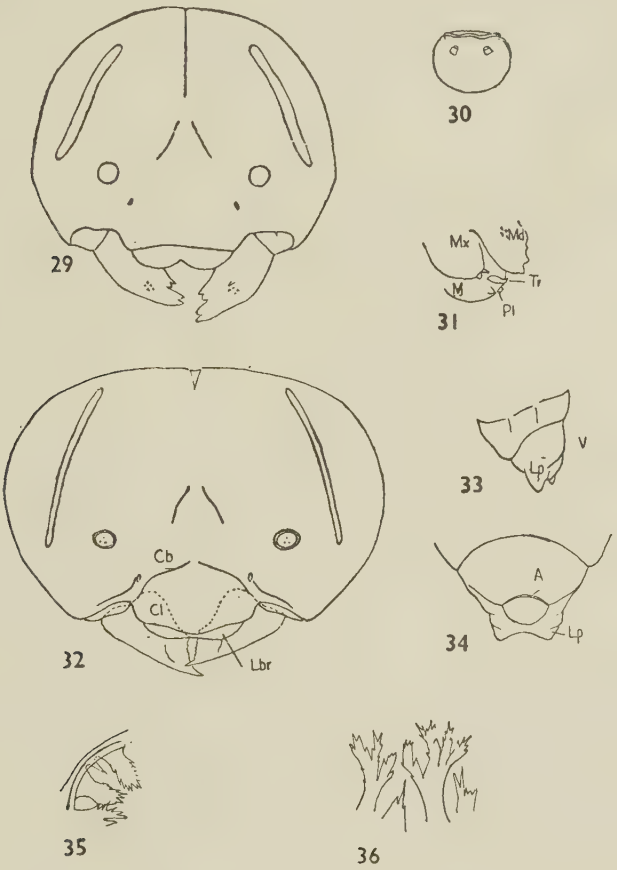
Vespa L.

Vespa crabro L.

The dried remains of three larvae of this species were obtained in the late autumn from an old nest; the heads were intact but the bodies were shrivelled

up and blackened; however, by soaking them in caustic potash, much of the cuticle was recovered, and from this mounts of the spiracles were made.

Head (fig. 37): Very similar to that of *Vespula vulgaris* (L.) except that it is larger; the anterior tentorial pits are less medial to the antennae and there are more sensillae upon the labrum (fig. 39).



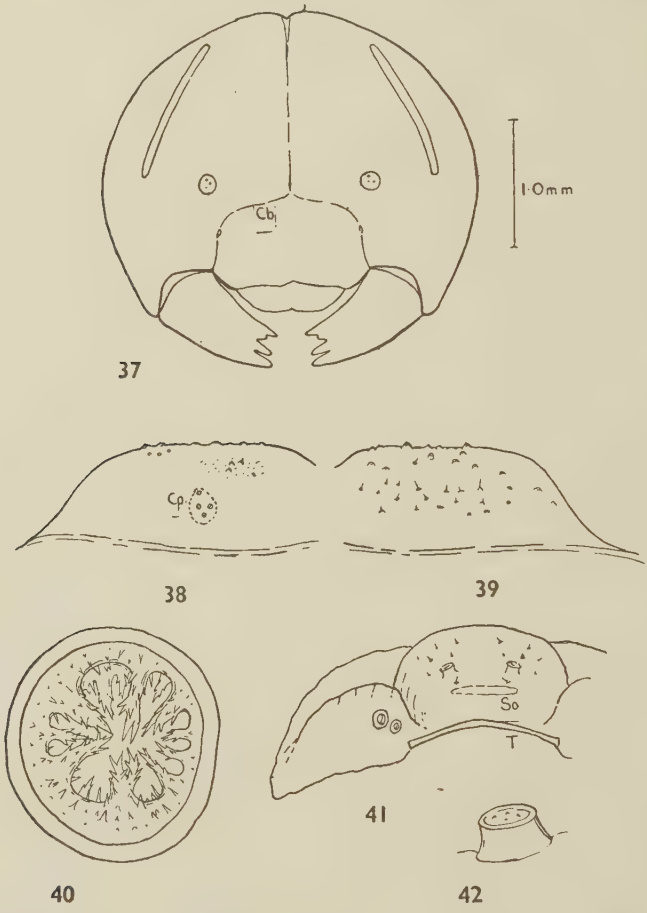
Figs. 29–36.—29–31. *Vespula rufa*. 29, Head capsule and mandibles; 30, Mentum, viewed from below to show the transverse ridge associated with the opening of the salivary gland; 31, Mentum etc., side view. M, mentum: Md, mandible: Mx, maxilla: Pl, labial papilla: Tr, transverse ridge. 32–35. *V. norwegica norwegica*. 32, Head capsule and mandibles. Cb, upper margin of clypeus: Cl, lower margin of clypeus: Lbr, labrum; 33, End of abdomen, side view, to show the lateral protuberances, Lp, on abdominal segment X: V, ventral surface; 34, End of abdomen, ventral view. A, anal slit: Lp, lateral protuberance; 35, Part of spiracle to show atrial processes; *V. media* (De Geer). 36, Atrial processes of a spiracle. After Semichon. Figs. 30–35 adapted from Grandi.

Spiracles: Relatively larger than those of *Vespula vulgaris*, with complex processes on the atrial walls, as shown in fig. 40.

Summary.

There appears to be no difficulty in finding subfamily characters for the larvae of the Vespinae, but with the incomplete examination of a few species

it is more difficult to pick upon likely specific characters. Possibly the shape of the mandibles and the spiracular processes would go a long way to separating the species. For instance, one sees from the figures that *Vespula norwegica norwegica* can be clearly separated from the other four species by the shape of the teeth on the mandibles; *Vespula rufa* (L.) can be distinguished from the other three by the presence of the spines on the mandibles, and *Vespula vulgaris*



Figs. 37–42.—*Vespa crabro*. 37, Head capsule and mandibles. Cb, upper margin of clypeus; 38, Palate. Cp, sclerotised patch with sensillae; 39, Labrum; 40, Spiracle; 41, Mentum and maxillae from above. So, opening of salivary gland: T, transverse bar as in *Vespula vulgaris*; 42, Labial papilla.

(L.) and *Vespa crabro* L. may be separated by the appearance of the spiracular processes. Consideration of *Vespula germanica* (Fabricius) must be postponed until a fuller description is available. Two points of interest arise out of this: the mandibles of *Vespula vulgaris*, *Vespula germanica* and *Vespa crabro* are identical, within the range of variation exhibited, and the heads as a whole are very similar; in fact from examination of the heads of the larvae one would say that *Vespula vulgaris* and *Vespula germanica* appear to be much closer to *Vespa crabro* in a different genus than they are to *Vespula norwegica norwegica* or even

Vespula rufa in the same genus. The other point concerns the spiracular processes which Semichon (1923) claims suffice to separate the species. I am somewhat sceptical of this. Nevertheless, if taken in conjunction with other characters, these processes may be very useful. Comparison of the processes in *Vespa crabro*, *Vespula norwegica norwegica* and *Vespula media* (De Geer), the latter figured by Semichon, shows that they are very similar, and one can well imagine that if figures were available for other species, conditions intermediate between these three might be found, and the differences would then be so small that it would be impossible to distinguish the species by means of this character alone. However, the presence of these processes seems to form a subfamily character.

Polistinae.

Of this subfamily there was material available of three South American species, and in addition figures and descriptions of two European species, *Polistes foederatus* Kohl and *P. gallicus* (L.), were examined. Thus the conclusions arrived at, though based on only five species, are enhanced in value by the fact that the species are drawn from both the New World and the Old World.

Characters of the subfamily.

The lower border of the clypeus is *not* ventral to the level of the bases of the mandibles; the mid-point of the lower border being dorsal to the bases of the mandibles.

There is more than one sensory bristle behind each labial papilla.

The maxillary lobes are prominent and nearly spherical.

The upper border of the clypeus is dorsal to the level of the anterior tentorial pits.

The anterior tentorial pits are lateral to or directly ventral to the antennae.

The last abdominal segment bears a median process dorsally.

In addition there are the following characters :—

The mandibles are slender, approximately circular in cross section, and end in two fine pointed teeth, of which the ventral is the larger and more terminal and sometimes (*Polistes carnifex* Fabricius) bears a small subsidiary tooth. The labrum is strongly transverse and is wider than, or as wide as, the distance between the antennae. Forked sensory bristles occur, particularly upon the mentum. They are not indicated in Soika's figures or his description of *P. gallicus* (L.). As Soika (1934) points out, the mentum is considerably longer than that of the Vespinae, which is often (*Vespula vulgaris* (L.)) somewhat transverse.

Key to the species of *Polistes* described.

1(2). With small spinous processes on the anterior border of the palate. With the upper one-third of the mentum colourless and the lower two-thirds dusky . . . . . *Polistes gallicus* (L.).

2(1). Without spines on the palate; the mentum not bicoloured.

3(9). With a pronounced knob on the dorsal half of the last abdominal segment. With more than three sensillae on each labial papilla.

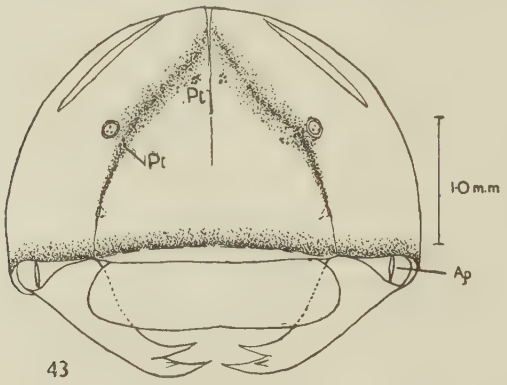
4(5). With a small third tooth on the largest tooth of each mandible. Head pale with conspicuous dark brown bands. Head capsule bearing long thin hairs . . . . . *P. carnifex* (Fabricius).

5(4). With only two teeth on each mandible. Head almost entirely dark brown and not bearing long hairs.

6(7). Head dark brown with a V-shaped pale mark coinciding with the frontal suture . . . . . *P. crinitus* var. *multicolor* (Olivier).

7(8). Head entirely dark brown, or with a pale area on the clypeus; if with pale marks on the frontal sutures, then with a pale area on the clypeus as well . . . . . *P. canadensis* var. *cinctus* Lepeletier.

8(3). Without a pronounced knob on the dorsal half of the last abdominal segment. With three sensillae on each labial papilla *P. foederatus* Kohl.



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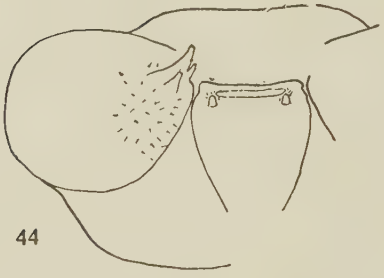

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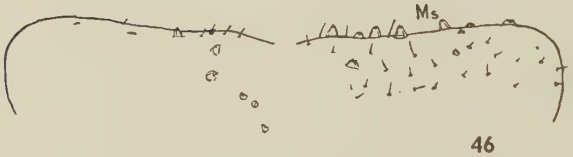

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Figs. 43–46.—*Polistes carnifex*. 43, Head capsule and mandibles. Ap, apodeme of mandible: Pt, punctation marking insertion of muscles; 44, Maxilla and labium from below; 45, Palate; 46, Labrum. Ms, conical sensillae.

Polistes Latreille.

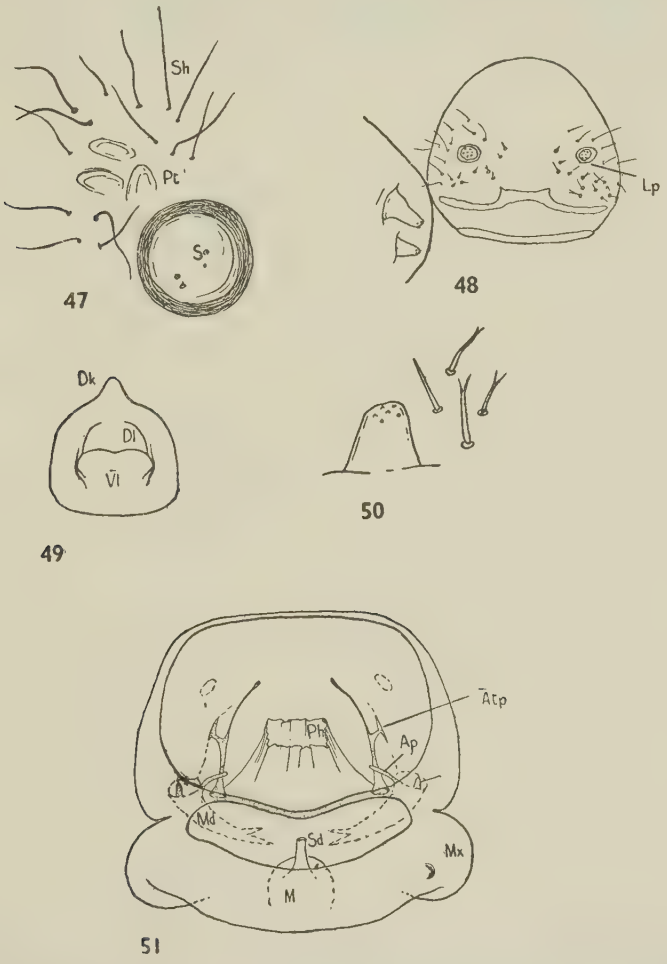
Three species examined at first hand.

Polistes carnifex (Fabricius).

This is a large species, the mature larvae being up to 20·0 mm. or more in length, and more stout in proportion than the larvae of *Vespula vulgaris* (L.). The general appearance is as shown in fig. 52, of *Polistes crinitus* Felton.

Head (see fig. 43): The head capsule is firm, for the most part pale or straw coloured, but with dark brown bands distributed as indicated in the figure by the stippling; these bands coincide with the frontal sutures, the lateral sutures of the clypeus, the anterior edge

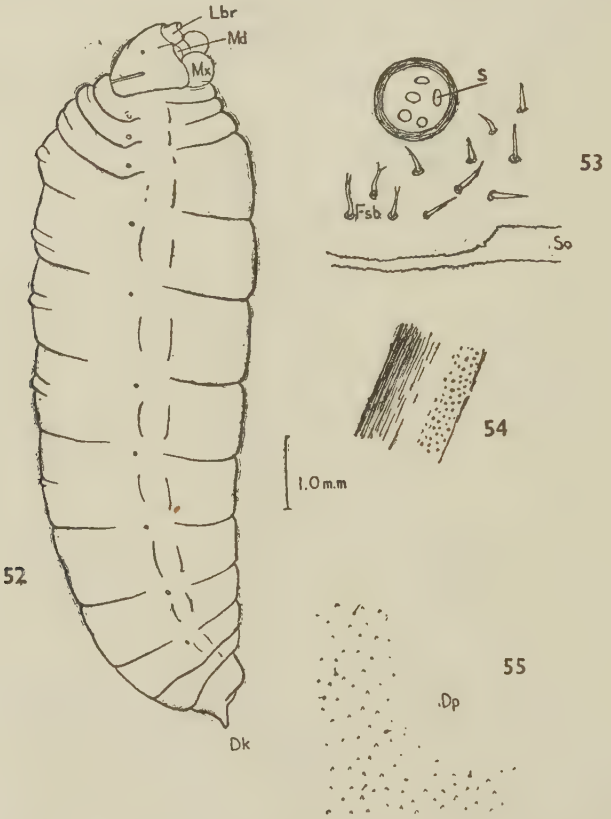
of the clypeus and the lower anterior border of the head capsule. The temporal bands are pale brown. The punctations which mark the insertions of muscles are particularly obvious. The antennae bear one or two small extra sensillae, in addition to the usual



FIGS. 47–51.—*Polistes carnifex*. 47, Antenna and adjacent part of head capsule, much magnified. Pt, punctation of muscle insertions: S, sensilla of antenna: Sh, sensory hairs; 48, Mentum and part of maxilla from above. Note group of sensory bristles, some forked, behind each labial papilla, Lp; 49, Anal segment viewed end on. Dl, dorsal lip of anus; Dk, median dorsal knob: Vl, ventral lip of anus; 50, Labial papilla and some of the sensory bristles which occur behind it (highly magnified); 51, Head capsule viewed from the rear, to show shape and position of the tentorium and apodemes of the mandibles, these structures being stippled. Ap, apodeme of mandible: Atp, anterior tentorial pit: Ph, pharynx: M, mentum: Md, mandible: Mx, maxilla: Sd, duct of salivary gland.

three (see fig. 47). As fig. 47 shows, the head capsule bears numerous long thin sensory hairs. The anterior tentorial pits are slightly lateral to the antennae. The lower border of the clypeus is at the same level as the bases of the mandibles; the upper border is not visible. The maximum width of the labrum is slightly greater than the maximum width

between the antennae. The mandibles when closed are mostly hidden beneath the labrum, when the head is viewed frontally as in fig. 43. The mandibles are rather slender, and bear two tapering sharp-pointed teeth, the lower and larger one with a small subsidiary tooth. The maxillary lobes are very prominent and approximately spherical. The labial papillae each bear six sensillae, but as usual this number shows some variation, five or seven sensillae being not uncommon. There is a group of about ten sensory bristles behind each



Figs. 52–55.—*Polistes crinitus* var. *multicolor*. 52, Side view of larva. Dk, median dorsal knob of abdominal segment X: Lbr, labrum: Md, mandible: Mx, maxilla; 53, Labial papilla, postpapillary sensory bristles, and part of the opening of the salivary gland. Fsb, forked sensory bristles: S, sensilla of antenna: So, opening of salivary gland; 54, Portion of temporal band, highly magnified. The right-hand side, showing punctations, is the outer border; 55, Part of the cuticle of the body, highly magnified, showing denticles and sensory bristles, but the portion of the dorsal protuberance, Dp, free of either.

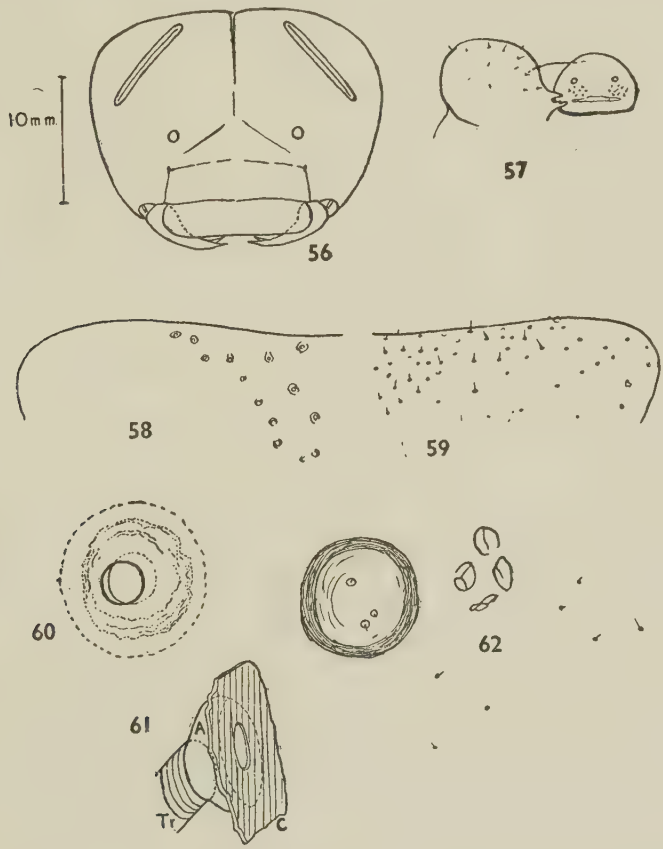
labial papilla and some of these are forked (see figs. 48 and 50). The tentorium or endoskeleton of the head is shown in fig. 51; so far as I can make out, it is the same as this in all Vespid larvae, but is hardly noticeable except in the species with well-sclerotised heads.

Body: The ventral surface of the thorax and first abdominal segment bear fine, rather long, hairs, visible with a binocular microscope. Dorsal and lateral protuberances are developed as usual. Abdominal segment X bears dorsally a prominent median knob, as shown in fig. 49, ventrally this segment is rather swollen; the ventral lip of the anus is slightly bifid.

Polistes crinitus Felton var. *multicolor* (Olivier).

Those larvae that were probably full grown were about 12·0 mm. long.

Head (fig. 56): The head capsule is dark brown with a V-shaped pale area coinciding with the frontal sutures; that is to say, the bottom of the V points towards the top of the head, and is roughly where the frontal sutures arise from the median suture, and the ends of the arms are at the level of the antennae.



Figs. 56–62.—*Polistes crinitus* var. *multicolor*. 56, Head capsule and mandibles; 57, Mentum and maxilla from above; 58, Palate; 59, Labrum; 60, Spiracle, surface view. Broken lines indicate structures beneath the cuticle; 61, Spiracle, side view, diagrammatic. A, atrium: C, cuticle: Tr, trachea; 62, Antenna and adjacent part of cuticle highly magnified. Compare fig. 47.

This character is liable to some variation; the larvae from the island of Dominica, from two nests, were as described, but those from the island of St. Kitts, also from two nests, tended to have the head rather paler in colour, the V-shaped area sometimes less clearly defined, and often accompanied by an additional pale area upon the clypeus.

The morphology of the head is similar to that of the preceding species, except that there are usually no extra sensillae in the antennae; the sensory bristles on the head capsule are small, short and sparse; there are more sensillae on the labrum, and the conical sensillae

are smaller. Normally there are five sensillae upon each of the labial papillae (fig. 53), and a group of about 10 sensory bristles behind each papilla, some of them being forked. The anterior tentorial pits are ventral to the antennae, but more or less lateral to the mid-points of them. It can be seen that the upper margin of the clypeus rises dorsally to the level of the anterior tentorial pits. There is no small tooth upon the larger of the two mandibular teeth, and these do not diverge from one another quite so widely. The mouth-parts are suffused smoky brown, whereas they are colourless in *P. carnifex*.

Body: Identical with that of the preceding species, except that it is much smaller, and the ventral half of the first thoracic segment is of similar appearance to the maxillae and labrum, being suffused smoky brown, more sclerotised than the rest of the body, and appearing rugosely punctured. The hairs upon the ventral surface of the thorax and abdominal segment I are less easy to see. No differences other than those described for the head appear to exist between the larvae from St. Kitts and those from Dominica. The spiracles are as shown in figs. 60, 61; a small ostium opens into a hemispherical atrium, the walls of which bear slightly crenate ridges; the trachea opens out of the bottom of the atrium by a hole of greater diameter than the ostium. Examination with high power of the piece of cuticle mounted with the spiracles shows that while the greater part of the cuticle is covered with evenly spaced minute denticles, and occasional sensory bristles, the cuticle of the dorsal protuberances is bare of either, see fig. 62.

Polistes canadensis (L.) var. *cinctus* Lepeletier.

Length about 15 mm.

Head: Identical with that of *P. crinitus* var. *multicolor* except for a difference in the colour markings.

Of 21 larvae from one nest, 11 had the head capsule dark brown all over, and 10 had an approximately circular pale area situated on the upper part of the clypeus and the lower part of the frons. Sixteen of the larvae from another nest had the head capsule dark brown all over, 8 had the pale area as described above, and 5 had ill-defined pale areas on the frontal sutures as well as on the clypeus and frons, but those on the frontal sutures could not be said to form a V. Three of the larvae from a third nest had the pale area on the clypeus and frons, and 2 had pale areas in the region of the frontal sutures as well.

Evidently Vespid larvae of the same species can vary from nest to nest, though it is uncertain how far, in this instance, the variation is due to differences of age in the larvae. It seems that these differences in the colour markings are probably not a satisfactory means of separating these two species; but the differences might be trustworthy and more sharply defined, if none but adult larvae just prior to the prepupal phase were compared.

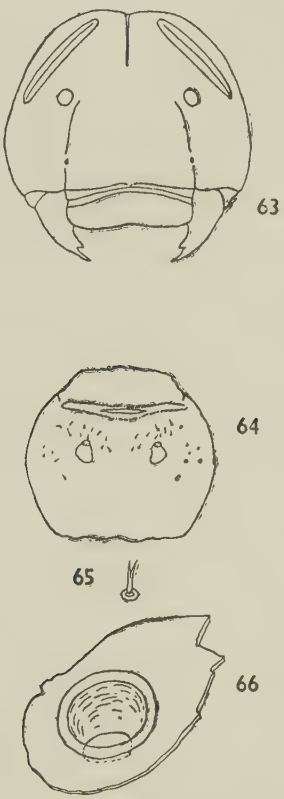
Body: Identical with that of the preceding species, except in size and the fact that the hairs on the ventral surface of the thorax and first abdominal segment are less conspicuous, being really difficult to see under the binocular microscope in this species.

Polistes foederatus Kohl.

Described and figured by Grandi (1934).

Head (see fig. 63): The head capsule bears numerous conspicuous sensory bristles. The anterior tentorial pits are directly ventral to the antennae. The upper margin of the clypeus is not shown; the lower margin is at the same level as the bases of the mandibles. The labrum is shown as being about as wide as the distance between the antennae. The mandibles bear only two teeth. There is a group of about 10 sensory bristles behind each labial papilla, and some of these are forked; each labial papilla bears 3 sensillae.

Body: Segment X of the abdomen is large, as in the species I have examined, but there is no prominent median dorsal knob, though Grandi says that it is produced into a median backwardly directed lobe; this evidently corresponds to the prominent knob. The ventral lip of the anus is bifid.



FIGS. 63–66.—*Polistes foederatus*. 63, Head capsule and mandibles; 64, Mentum, from below; 65, A forked sensory bristle; 66, Spiracle. Figs. 63–66 adapted from Grandi.

Grandi interprets the spiracles as shown in fig. 66, but I am inclined to doubt if this is correct; at first I thought the spiracles of *P. crinitus* were of this shape and it was only after noting most carefully at what level, under the high power, each feature was in focus, that the interpretation shown in figs. 60, 61, was arrived at.

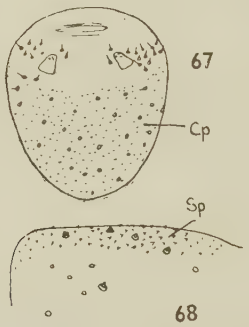
Polistes gallicus (L.).

Described and figured by Soika (1934).

Head: This is dusky coloured except for the antennae, median suture, 2 lines on the occiput (presumably the temporal bands), bases of the mandibles and the adjacent portions of the head (the pleurostomae), the maxillae and the proximal portion of the mentum. The head bears numerous long hairs. The mandibles are of normal shape; bidentate; the smaller tooth slightly mobile. The palate bears on its anterior margin numerous small spinous processes. The mentum has the upper one-third colourless and the remainder dusky coloured, the line of demarcation between the two areas being fairly sharp. These

last two characters appear to be the most distinctive of this species, figs. 67 and 68. No forked sensory bristles are described. The body is not described.

Peltrera (1935) has investigated the variability of some of the buccal structures of the head in the larvae of *P. gallicus*. He examined eight larvae from the same nest; seven of these were adult, having been taken from closed cells, and one had not reached the adult stage. Peltrera found a wide variation in the number and positions of the various sensillae on the labrum and labium, with frequently a considerable bilateral asymmetry in numbers and position of the sensillae in one individual. Sometimes the sensillae are arranged in a roughly symmetrical manner, but never strictly so. The internal papilla of the maxilla, or terminal process of the maxilla as Peltrera calls it, since he agrees with Grandi in calling the external one the maxillary palp, is usually bilobed, but exhibits considerable variation in the number of secondary lobes each of the main lobes bears; there is usually bilateral asymmetry. My own conclusions



Figs. 67–68.—*Polistes gallicus*. 67, Mentum, from below. Coloured portion, Cp, indicated by stippling; 68, Palate to show spinous processes, Sp. Figs. 67–68 adapted from Soika.

agree in general with these results and consequently I have made very little use of characters connected with these sensory structures of the mouth-parts. Peltrera found, however, that the shape of the maxillary palp and the labial palp is constant in each case and that each bears terminally three sensillae. Although the mandibles are normally bidentate in *P. gallicus*, Peltrera illustrated one mandible with a small third tooth; the other mandible of the pair was normal. Peltrera confirmed Soika's observation that the labium is bicoloured. It is important to note that the young larva examined by Peltrera differed considerably in the number and arrangement of the sensillae upon the labrum and labium, and in the shape of the terminal process of the maxilla, from the condition of these structures prevailing in the adult larvae.

Conclusions.

The larvae of the Polistinae seem to form an even more compact and easily recognised subfamily than those of the Vespinae; the shape of the head capsule appears to be much more constant and the mandibles show a smaller range of variation. The shape of the mandibles and the rectangular appearance of the labrum seem to be characteristic of the subfamily. This smaller range of variability would probably make it more difficult to separate the larvae of the species of *Polistes* than to separate those of the Vespinae. The instance of

P. crinitus and *P. canadensis* appears to support this view, for though hardly distinguishable as larvae, the adults are apparently quite distinct, though they do belong to the same species group.

Polybiinae.

The greater part of the material examined belonged to this subfamily, and, as the list at the beginning shows, there were specimens of twenty species divided among six genera. Of these six genera, only two appear to be closely related, so that the subfamily characters given below possess a considerable degree of certainty.

Subfamily characters.

The median point upon the lower margin of the clypeus is dorsal to a line drawn between the points of insertion of the mandibles into the head capsule.

There is only one sensory bristle behind each labial papilla.

The width of the labrum is usually less than, but never greater than, the distance between the antennae.

The anterior tentorial pits are medial to, or occasionally ventral to, the antennae.

The upper margin of the clypeus is dorsal to the anterior tentorial pits.

The following characters are less definite or less constant :—

The mandibles are approximately circular in cross section and soft, except sometimes towards the tips; there are not more than two teeth, and of these usually only the terminal one is large and this is most often slender, tapering and curved. Forked sensory bristles are often present upon the mouth-parts and occasionally upon the labrum. Many of the genera contain mostly small species, with soft, colourless, unsclerotised heads; in such species the median suture, the lateral margins of the clypeus from the anterior edge of the head capsule as far as the anterior tentorial pits, and the points of insertion of muscles, are marked by comparatively wide depressions, circular or groove-like in shape.

Key to the genera *Polybia*, *Protopolybia*, *Nectarinia*, *Stelopolybia*, *Metapolybia*, and *Mischocyttarus*.

1(2). With one or more large symmetrically placed lobes upon the ventral surface of the first abdominal segment. Diameter of the first spiracle at least twice as great as that of the others . . . . *Mischocyttarus* Saussure.

2(1). Without lobes upon the ventral surface of the first abdominal segment. First spiracle not much larger than the rest.

3(6). Mandibles with a secondary tooth upon the upper margin.

4(5). Mentum only about half the width of the labrum. Head capsule at least partially brown. Forked bristles occur on the head *Metapolybia* Ducke.

5(4). Mentum considerably more than half the width of the labrum. Head colourless. No forked sensory bristles occur upon the head *Stelopolybia* Ducke.

6(3). If the mandibles have a secondary tooth it is upon the lower margin.

7(8). Maximum width between the bases of the mandibles equal to the maximum width between the bases of the maxillary lobes. No forked bristles occur . . . . . *Nectarinia* Shuckard.

8(7). Maximum width between the bases of the mandibles less than that between the bases of the maxillary lobes. Forked bristles occur *Polybia* Lepeletier and *Protopolybia* Ducke.

Polybia Lepeletier.

Four species examined at first hand.

Characters of the genus.

The mandibles have one main terminal tooth and a small secondary, sharp or blunt or sometimes much reduced, upon the ventral surface of the mandible.

The maximum distance between the bases of the mandibles is less than the maximum distance between the bases of the maxillary lobes (cf. *Nectarinia*).

The mentum is more than half as wide as the labrum.

The head capsule is colourless or pale straw coloured, and commonly has wide depressions marking the insertions of muscles, the position of the median suture, etc.

Forked sensory bristles occur upon the head, particularly upon the mouth-parts.

Key to the species of *Polybia* examined.

1(2). Width of the labrum subequal to the distance between the antennae. Having conspicuous dorso-lateral prominences upon abdominal segment X . . . . . *micans* Ducke.

2(1). Width of the labrum clearly less than the distance between the antennae. Without conspicuous dorso-lateral prominences on abdominal segment X.

3(6). With a median dorsal prominence on abdominal segment X.

4(5). Secondary tooth of the mandibles only a rounded hump. With inconspicuous dorso-lateral prominences on abdominal segment X *bistriata* (Fabricius).

5(4). Secondary tooth of the mandibles comparatively sharp. Without dorso-lateral prominences on abdominal segment X . . *rejecta* (Fabricius).

6(3). Without a median dorsal prominence on abdominal segment X *catillifex* Moebius.

Polybia micans Ducke.

About 15·0 mm. long.

Head (see fig. 69): The head capsule is fairly firm and is colourless, except for the temporal bands and antennae, which are light brown. There are a number of broad shallow depressions in the head capsule, which mark the insertion of muscles; they correspond to the punctations in those species with more sclerotised heads. There is a projecting lobe of the head capsule exterior to, and slightly below, the base of each mandible (see figs. 69 and 70); this is commonly present in Vespid larvae, but is rather prominent in this species; this portion of the head capsule seems to be what Grandi calls the pleurostoma.

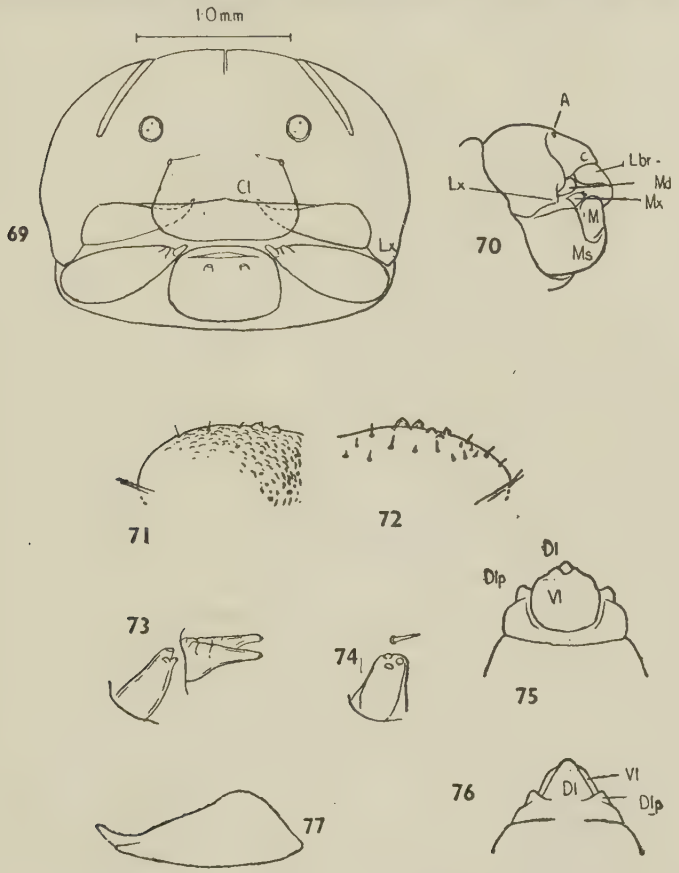
The anterior tentorial pits are just medial to the antennae. There are a few bristles on the head capsule. The surface of the labrum anteriorly is slightly rugose, the palate very rugose. The labrum bears about 6 conical sensillae on each side of the median line; its width is about equal to the distance between the antennae. The mentum is more than half as wide as the labrum. The mandibles are as figured. There are 3 sensillae upon each labial papilla and one sensory bristle behind each papilla; some of the sensory bristles upon the mouth-parts are forked.

Body: This is normal, except for the shape of abdominal segment X, which is distinctive (see figs. 75 and 76); the dorsal and ventral lips of the anus are comparatively long, the ventral lip is bifid as usual, and there are two dorso-lateral prominences directed backwards; this last feature is the most distinctive one.

Polybia rejecta (Fabricius).

Full-grown larva about 10·0 mm. long.

Head (fig. 78): Identical with that of the preceding species, except in the following details. It is smaller and sometimes there is some pale brown on the capsule. The lobes of the head capsule adjacent to the mandibles are less developed. There are more round



Figs. 69–77.—*Polybia micans*. 69, Head. Cl, lower border of clypeus: Lx, lobe of head capsule exterior to base of mandible; part of the pleurostomal region; 70, Side view of head. A, antenna: C, clypeus: Lbr, labrum: Lx, pleurostomal lobe, see fig. 69. M, mentum: Md, mandible: Mx, maxilla: Ms, submentum; 71, Palate; showing rugosity; 72, Labrum; 73, Maxillary papillae; 74, Labial papilla and postpapillary sensory bristle; 75, Anal segment, ventral view. Dl, dorsal lip of anus: Dlp, dorsolateral protuberance: Vl, ventral lip of anus; 76, Anal segment, dorsal view. Letters as in fig. 75; 77, Mandible; front view.

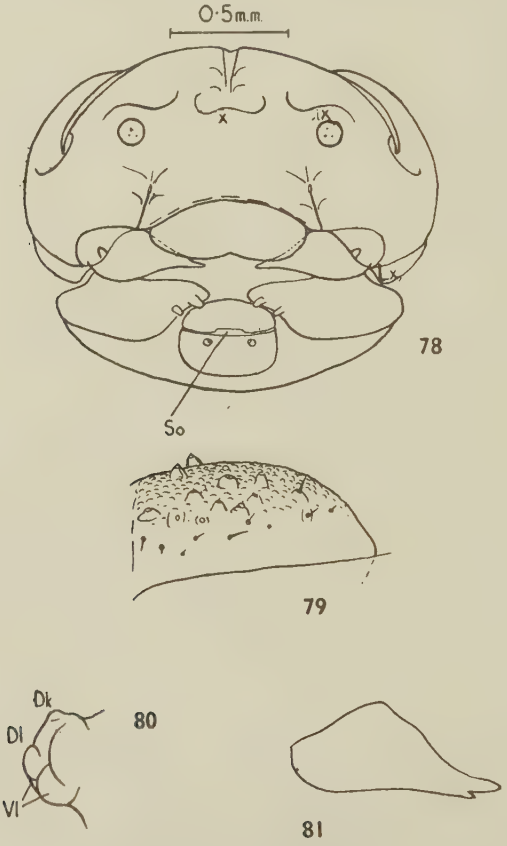
sensillae upon the labrum, the anterior part of which is strongly rugose; its width is less than the minimum distance between the antennae. The mandibles, see fig. 81, are slightly different.

Body: The same as in the preceding species, except for abdominal segment X; the dorsal and ventral lips of the anus are of normal length, the latter bifid, and there are no dorsolateral prominences. As fig. 80 shows, there is a low prominence in the median line on that part of abdominal segment X above the dorsal lip of the anus.

Polybia catillifex Moebius.

Length about 8·0–9·0 mm.

Head (fig. 82): The same as that of *P. rejecta*. The only difference that seems worth noting is in the shape of the opening of the salivary gland; that of *P. rejecta* extends from side to side of the mentum, the edges of the slit not converging towards one another near the side of the mentum, but remaining parallel to one another. In *P. catillifex* this opening does not extend quite to the sides of the mentum and the edges converge and meet.



Figs. 78–81.—*Polybia rejecta*. 78, Head. So, opening of salivary gland: X, line indicating the lower margin of a depression: Lx, pleurostomal lobe; 79, Labrum showing rugose appearance; 80, Anal segment viewed laterally. Dl, dorsal lip of anus: Dk, median dorsal prominence: Vl, ventral lip of anus; 81, Mandible; front view.

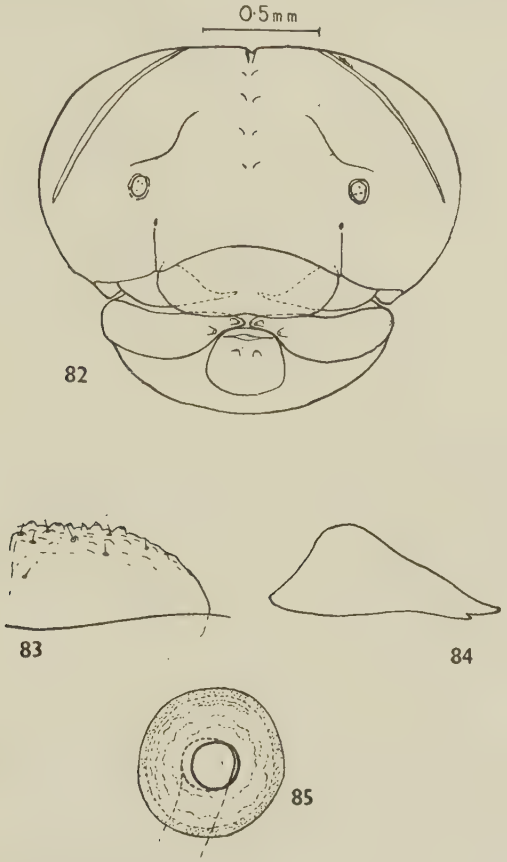
Body: Similar to that of the preceding species, except that there is no median dorsal prominence on abdominal segment X. The spiracles are as shown on fig. 85, the structure being the same as that described in *Polistes crinitus* Felton.

Polybia bistriata (Fabricius).

Length about 6·0 mm.

Head (fig. 86): Identical with that of *P. catillifex*, except that the single sensory bristle behind each labial papilla is usually forked, while it is usually unforked in *P. catillifex*, and in addition the secondary tooth on the mandible is replaced by a blunt hump.

Body: Similar to that of *P. rejecta*, there being a median dorsal prominence on abdominal segment X; there are also slight dorso-lateral prominences in the same position as those of *P. micans*.



FIGS. 82–85.—*Polybia catillifex*. 82, Head; 83, Labrum; 84, Mandible, front view; 85, Spiracle; surface view. Compare figs. 60 and 61.

CONCLUSIONS.

From these descriptions it is evident that the species of *Polybia* are generally very similar and difficult to distinguish, while such differences as can be discovered are seldom clear-cut or easy to describe or use. One can make a key such as that given to the 4 species described, but it might be very difficult to make a key to a large number of species.

Protopolybia Ducke.

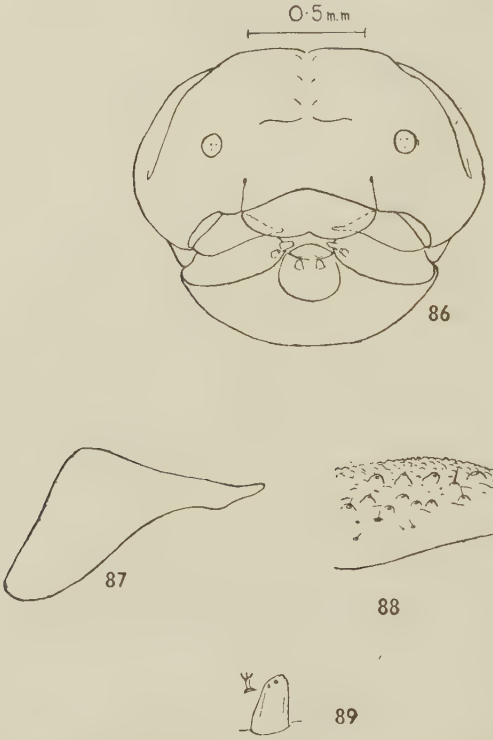
Two species examined at first hand.

Generic characters.

The characters of the genus are the same as those given for *Polybia*, but the secondary tooth is not always present upon the mandibles and the head capsule is not always colourless.

The two species may be distinguished as follows :—

Mandibles with only a single terminal tooth . . *P. minutissima* (Spinola).
Mandibles with a secondary tooth upon the ventral margin *P. sedula* (Saussure).



Figs. 86–89.—*Polybia bistriata*. 86, Head; 87, Mandible; front view; 88, Labrum; 89, Labial papilla and trifid postpapillary sensory bristle.

Protopolybia minutissima (Spinola).

Length about 6·0 mm.

Head (fig. 90) : The head capsule is suffused light smoky brown with the median suture, antennae and temporal bands colourless; it bears numerous short sensory bristles visible under the binocular. There are depressions in the head capsule as described for the preceding genus. The anterior tentorial pits are medial to the antennae.

The lobe of the head capsule exterior to the base of each mandible is hardly developed. The anterior part of the labral surface is rugose and the sensory bristles are large; the width of the labrum is less than the minimum distance between the antennae. The mandibles have only a single terminal tooth. The mentum is more than half the width of the labrum. There is one sensory bristle behind each labial papilla and some of the bristles upon the mouth-parts are forked.

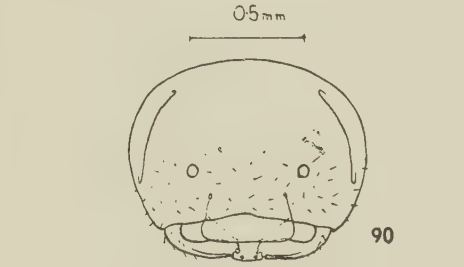
Body : The only part of this which needs mention is the terminal segment; the ventral lip of the anus is bifid, and there are low rounded lateral humps.

Protopolybia sedula (Saussure).

Length about 6·0 mm. Though the same length as the preceding species, it is not so slender.

Head (fig. 94): Differs from that of *P. minutissima* in the following respects. It is colourless and shows a slight punctation; there are only a few hairs on it. The lobes of the head capsule exterior to the bases of the mandibles are normally developed. The sensory bristles on the labrum are relatively smaller and the mandibles bear a secondary tooth upon the lower surface as in *Polybia*.

Body: As in the preceding species.



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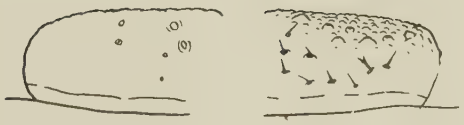

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FIGS. 90–93.—*Protopolybia minutissima*. 90, Head; 91, Palate; 92, Labrum; 93, Mandible; front view.

CONCLUSIONS.

By examination of the species described above, I have been unable to find any certain means of separating this genus from *Polybia*. It seems that the lobes of the head capsule exterior to the base of each mandible are rather more developed in the species of *Polybia* than is normal. In *Polybia* the anterior margin of the labrum is excised (this only amounts to a slight emargination in *P. micans* and *P. catillifex*), while it is truncate in the two species of *Protopolybia*. The larvae of many more species of both genera will have to be examined in order to decide whether or not these two genera can be distinguished from one another in the larval state.

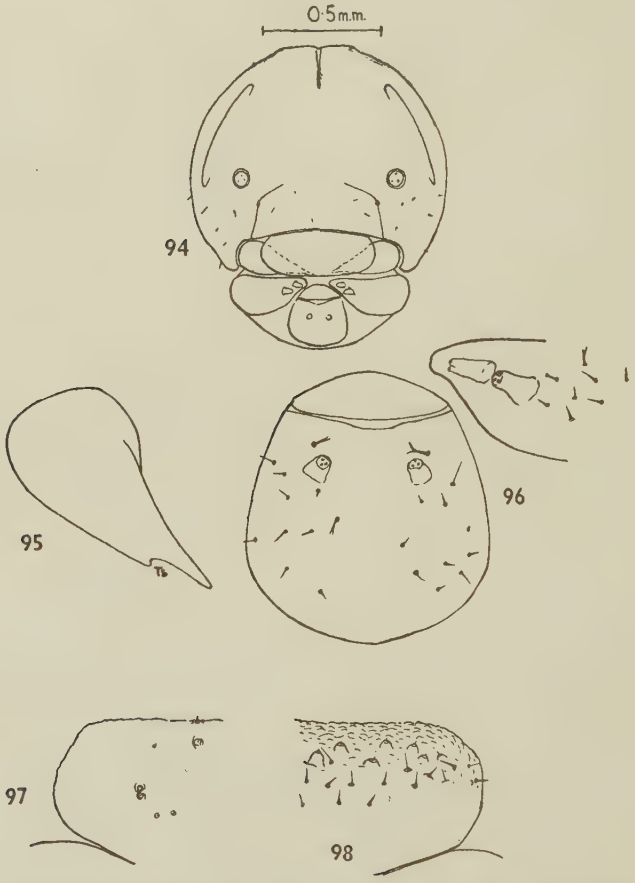
Nectarinia Shuckard.

One species examined at first hand.

Nectarinia scutellaris (Fabricius).

Length about 7·0 mm.

Head (fig. 99): The head capsule is softer than in *Polybia* and *Protopolybia*; it is colourless, with numerous bristles much as in *Protopolybia minutissima*. The anterior tentorial pits are medial to the antennae. The anterior portion of the surface of the labrum

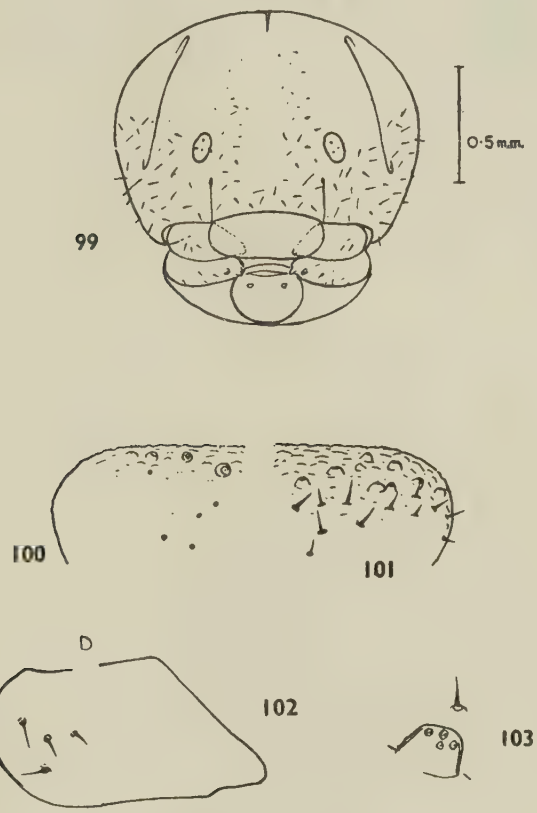


Figs. 94–98.—*Protopolybia sedula*. 94, Head; 95, Mandible; half front view, the secondary tooth, Ts, is upon the lower edge; 96, Mentum and maxilla from below; 97, Palate; 98, Labrum.

is rugose. The mandibles are as shown in fig. 102. The greatest width between the bases of the mandibles is the same as the greatest width between the bases of the maxillary lobes, so that the bases of the mandibles more or less coincide with those of the maxillary lobes; this is not so in the two preceding genera, the mandibles being closer together than the maxillary lobes. There are some bristles on the outer face of each mandible. The mentum is more than half the width of the labrum, the width of which is about equal to the distance between the antennae. There is one sensory bristle behind each labial papilla, and each papilla bears 3 or 4 sensillae. No forked bristles could be seen.

Body: Normal. The ventral lip of the anus is bifid, there is no median dorsal knob

and no dorso-lateral protuberances on abdominal segment X. The spiracles are similar to those of *Polistes crinitus*.



FIGS. 99–103.—*Nectarinia scutellaris*. 99, Head; 100, Palate; 101, Labrum; 102, Mandible; front view. D, base of mandible; 103, Labial papilla and postpapillary sensory bristle.

Nectarinia lecheguana (Latreille).

There is a brief description of the larva of this species and a drawing of the head, by du Buysson (1905). It is difficult to make out anything from the drawing, but du Buysson describes the mandibles as ending in a single fine point, which is rather surprising, considering their shape in *N. scutellaris*. Owing to the apparent disagreement between the characters of *N. lecheguana* as figured and described by du Buysson, and those of *N. scutellaris* as given here, I have not stated any possible generic characters for the genus *Nectarinia*.

Stelopolybia Ducke.

One species examined at first hand.

Generic characters.

The following seem to be the most likely generic characters :—

The sides of the labrum are divergent from one another where they join the clypeus.

The mentum is at least three-quarters as wide as the labrum, whereas it is seldom more than two-thirds as wide in the other genera of the Polybiinae examined.

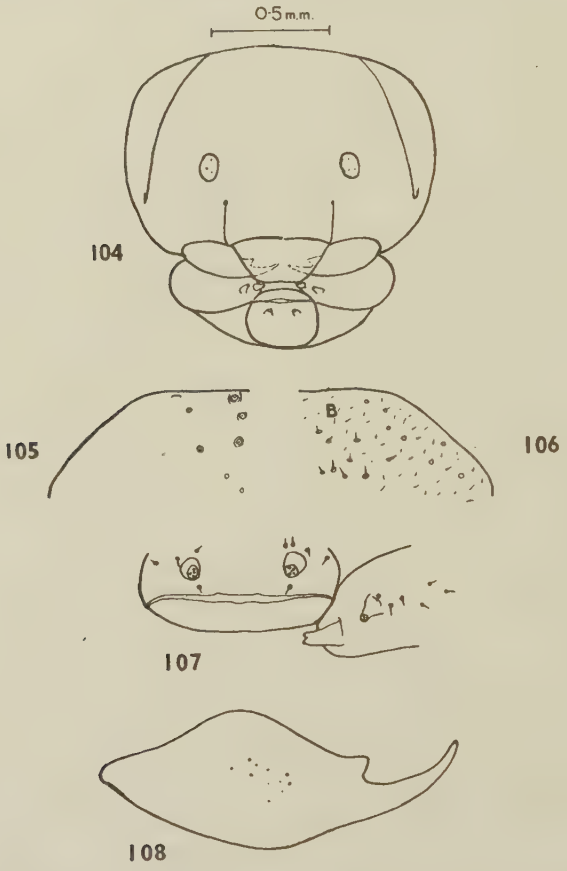
The secondary tooth of each mandible is upon the dorsal margin.

The non-rugose surface of the labrum and the presence upon it of small spines in addition to the usual articulated sensory bristles, coupled with the absence of forked sensory bristles, might prove to be useful characters.

Stelopolybia infernalis (Saussure).

Length about 8·0–9·0 mm.

Head (fig. 104): The head capsule is soft and entirely colourless. The anterior tentorial pits are medial to the antennae. The sides of the labrum diverge from one another, even



Figs. 104–108.—*Stelopolybia infernalis.* 104, Head; 105, Palate; 106, Labrum. B, non-articulate bristles; 107, Mentum and maxilla from above; 108, Mandible; front view. The secondary tooth is upon the upper border.

at the point where they join the clypeus, instead of being convergent as in the preceding genera. The upper surface of the labrum is not rugose, and bears, in addition to the usual sensory bristles, a number of evenly spaced, very small bristles which are cuticular processes, as opposed to cuticular appendages, such as the sensory bristles. Conical sensillae are few or absent, though present upon the palate. The mandibles are as figured, with a

secondary tooth upon the upper margin and a long curved main tooth, and there are some minute sensillae upon the outer surface of each mandible. The mentum is considerably more than half the width of the labrum, which is less wide than the distance between the antennae. There is one sensory bristle behind each labial papilla, and the labial papillae bear 4–5 sensillae. No forked bristles could be discovered. The position of the mandibles in relation to the maxillary lobes is the same as in *Polybia* and *Protopolybia*, as opposed to the condition in *Nectarinia scutellaris*.

Body: This is the same as described for the preceding genera of the POLYBIINAE; abdominal segment X is simple with no median dorsal knob or dorso-lateral prominences; the ventral lip of the anus is bifid.

Metapolybia Ducke.

One species examined at first hand.
The most likely generic characters are these :—

The secondary tooth of the mandibles is upon the upper margin and the point of each mandible is long and curved.

The mentum is only about half the width of the labrum.

The head capsule is coloured.

Forked bristles occur.

Metapolybia cingulata (Fabricius).

About 8·0 mm. long.

Head (fig. 109): The head capsule is smoky brown, except for areas around the temporal bands, the median suture and the antennae, which are colourless; the lower part of the clypeus and all the labrum are also colourless. The anterior tentorial pits are medial to the antennae. There are a few short, stout, blackish bristles upon the lower part of the genae. The anterior surface of the labrum is rugose, the margins slightly convergent where they join the clypeus; the width of the labrum is slightly less than the distance between the antennae. The mandibles are smoky brown with a long, hooked, sharp-pointed, terminal tooth and a small secondary tooth upon the upper border; also some small sensillae upon the outer surface, see fig. 113. The mentum is only about half the width of the labrum. There is one sensory bristle behind each labial papilla and forked bristles occur upon the mouth-parts. The labial and maxillary papillae are brown.

Body: Normal. Abdominal segment X is without a median dorsal prominence, though there are slight dorso-lateral prominences. The dorsal lip of the anus is rather pointed; the ventral lip is only very slightly bifid.

Mischocyttarus Saussure.

Eleven species examined at first hand.

Characters of the genus.

There is always one or more symmetrically placed lobe upon the ventral surface of the first abdominal segment.

The first thoracic spiracle is at least twice the diameter of any of the succeeding spiracles.

The labrum is large, retractible beneath the clypeus, and more than twice as wide as the mentum. Its width is slightly less than the distance between the antennae.

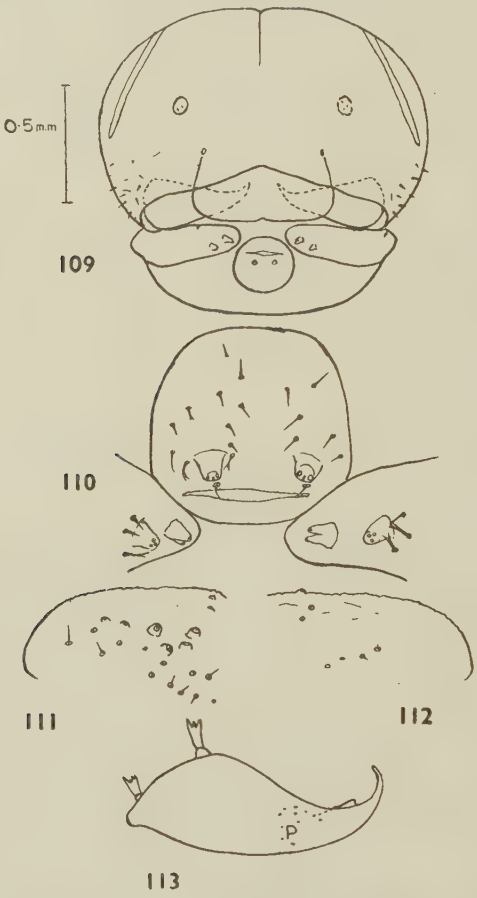
The mandibles are slender and terminate in a single, long, thin, curved and fine-pointed tooth.

The head capsule is sclerotised and always, at least partially, of some shade of brown.

There are few bristles upon the mouth-parts and none of them is forked.

The median point on the lower margin of the clypeus does not come below a line drawn between the points of insertion of the mandibles into the head capsule, though the lateral parts of this clypeal margin do.

The anterior tentorial pits are ventral to the antennae.



Figs. 109–113.—*Metapolybia cingulata*. 109, Head; 110, Mentum and maxilla from above; 111, Palate; 112, Labrum; 113, Mandible; front view. P, small processes, perhaps sensillae.

Key to the eleven species.

1(10). No bristles upon the ventral surface, other than those upon the abdominal lobes.

2 (7). Abdominal lobes parallel to one another and broadly rounded at the ends. No median dorsal knob on abdominal segment X.

3 (6). Head capsule brown with pale patches. Labrum colourless. Bristles of the abdominal lobes greyish to almost black.

4 (5). Genae and clypeus deep brown to black, rest of the head capsule straw coloured. Bristles of the abdominal lobes numerous, fine, greyish to dark brown . . . . . *oecothrix* Richards.

5 (4). Genae suffused smoky brown, clypeus and rest of the head capsule straw coloured. Bristles of the abdominal lobes coarse, brown to blackish, and not more numerous than usual . *synoecus* Richards.

6 (3). Head capsule dark brown all over. Labrum brown. Bristles of the abdominal lobes pale straw coloured
cerberus Ducke var. *acheron* Richards.
7 (2). Abdominal lobes diverging from one another, each tapering to a fine point. A median dorsal knob on abdominal segment X.
8 (9). Bristles on the abdominal lobes thickened distally and truncate.
metoecus Richards.
9 (8). Bristles on the abdominal lobes tapering to a point in a normal manner.
lecointei (Ducke).
10 (1). Bristles present on the ventral surface, beside those upon the abdominal lobes.
11(14). Ventral bristles inconspicuous, arising more or less vertically from the surface of the abdomen.
12(13). With 3 abdominal lobes and with a median dorsal knob on abdominal segment X . . . . . *carbonarius* (Saussure).
13(12). With two abdominal lobes and no median dorsal knob upon abdominal segment X . . . . . *collarellus* Richards.
14(11). Ventral bristles coarse and conspicuous, not arising vertically from the surface of the abdomen, but directed strongly backwards.
15(20). With 2 abdominal lobes.
16(19). Abdominal lobes parallel to one another and pointed. Conspicuous colourless areas present on the genae.
17(18). Anterior border of the labrum brown. Ventral bristles on segments IV–IX. Abdominal lobes with blunt points . . . . . Sp. 10.
18(17). Labrum colourless. Ventral bristles on segments II–VIII. Abdominal lobes with fine points . . . . . *surinamensis* (Saussure).
19(16). Abdominal lobes strongly divergent from one another and with the ends broadly rounded. Genae brown, of the same colour as the rest of the head capsule . . . . . *superus* Richards.
20(15). With one median abdominal lobe . . . . *injucundus* (Saussure).

As this key indicates, these eleven species of *Mischocyttarus* larvae fall quite clearly into several groups. The following is a table of the apparent affinities of the species.

A. Having no ventral bristles other than those upon the abdominal lobes.

Group I. *lecointei, metoecus.*

Very close to one another, the only difference being the shape of the bristles on the abdominal lobes.

Group II. *cerberus, oecothrix, synoecus.*

With blunt, parallel, abdominal lobes, having bristles all over them, as opposed to the sharp, divergent lobes with bristles restricted to the bases of Group I. Having no knob on abdominal segment X, unlike Group I.

M. oecothrix and *M. synoecus* are much closer to one another than to *M. cerberus* and they form a subgroup. Both have the head capsule parti-coloured, the labrum colourless and the bristles of the abdominal lobes dark coloured; while *M. cerberus* has the head brown all over, the labrum brown and the bristles of the abdominal lobes very pale.

B. Having ventral bristles besides those on the abdominal lobes.

Group III. *collarellus, carbonarius.*

Both have inconspicuous bristles arising vertically from the surface of the abdomen; otherwise they appear to have no particular affinities to one another.

Group IV. *injucundus, superus, surinamensis,* Sp. 10.

All have the conspicuous backward sloping ventral bristles. There appears to be nothing else to connect *injucundus* to *superus*, except perhaps the rather conspicuous sensillae upon the palate of both, but in view of the distinctness of *injucundus*, which has only one abdominal lobe, this similarity of the sensillae is probably a coincidence.

Sp. 10 and *surinamensis* are close to one another and form a subgroup; in both the genae bear characteristically shaped colourless patches, and the abdominal lobes are parallel to one another and pointed.

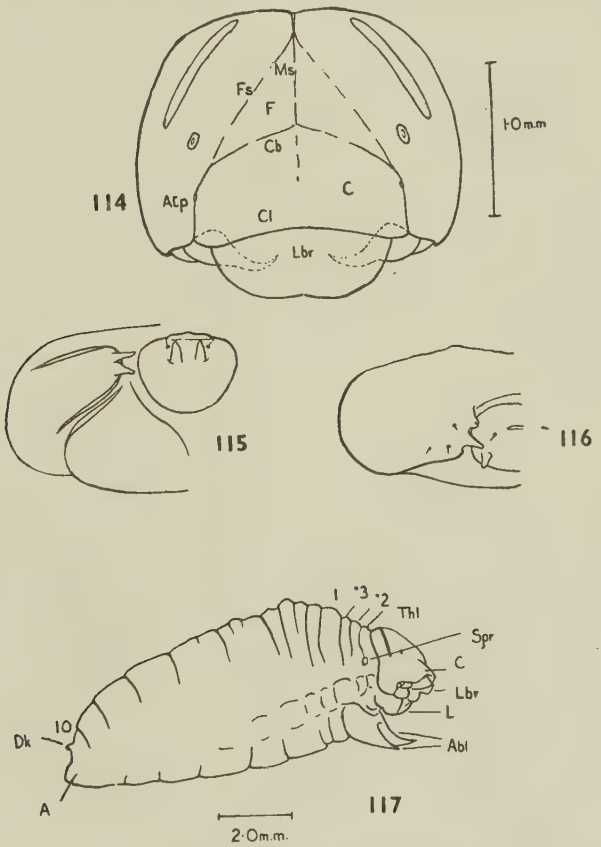
Mischocyttarus lecointei (Ducke).

Length about 9·0 mm.

Head: The head capsule and mouth-parts are brown, except for the temporal bands, the median suture, antennae and the lower border of the clypeus. The head capsule is firm and dark brown, the labrum, maxillae and labium, and the mandibles are smoky brown. The clypeus appears sparsely and irregularly punctured; the sensory bristles of the head capsule are few and minute. The anterior tentorial pits are beneath the antennae. The median point on the lower border of the clypeus is dorsal to a line drawn between the points of insertion of the mandibles into the head capsule, though the corners of the lower border of the clypeus are ventral to this line, unlike the condition in the preceding genera. The labrum can be partially retracted beneath the clypeus, and when retracted appears to arise from beneath the clypeus; this is made possible by an area of membrane which separates the clypeus from the labrum. The labrum is considerably longer from front to back than in the preceding genera of the Polybiinae; it is nearly as wide as the distance between the antennae; the sensillae upon it are small and inconspicuous and the surface is not rugose. There are a few rather larger sensillae upon the palate. The mandibles have no secondary teeth, each terminates in a long thin curved and finely pointed tooth, which is directed down the throat when the mandibles are closed. The mentum is considerably less than half as wide as the labrum; both maxillary and labial papillae are long in comparison with those of the preceding Polybiine genera. There is a single sensory bristle behind each labial papilla and only very few sensory bristles upon the mouth-parts; no forked bristles occur.

Body: The thorax has the lateral protuberances developed, the first thoracic spiracle is very large and obvious, being at least twice the diameter of the other spiracles (see figs. 124–126). The abdomen has the dorsal and lateral protuberances developed. The ventral portion of the first abdominal segment, between the lateral protuberance, is developed into a pair of large lobes (see figs. 117 and 127–134); each of these is circular in cross section and tapers to a comparatively fine point; the lobes are symmetrical and equal in length to the length of the head capsule, measured from the top to the labrum; they are directed forwards and diverge from one another. Each lobe has a few large sensory bristles upon its outer surface, particularly near the base. In future these lobes will be called "the abdominal lobes"; for further information about them see page 326. The corresponding part of abdominal segment II is swollen, but is not produced into lobes. The remainder of the abdomen conforms to the usual Vespid type and is without bristles. The ventral lip of the anus is bifid and there is a small abrupt knob in a median dorsal position on abdominal

segment X. The structure of the spiracles is as shown in figs. 124–126; the large first spiracle is wide open, with the usual crenate ridges on the atrial wall, the bottom of the atrium is partially closed by a diaphragm, pierced by the tracheal opening. The smaller figure is of one of the abdominal spiracles, drawn to the same scale; it has the mouth of the spiracle partially closed by a very thin diaphragm so that it is constructed in the same



FIGS. 114–117. 114, *Mischocyttarus occothrix*. Head. Atp, anterior tentorial pit: C, clypeus: Cl, lower margin of clypeus: F, frons: Fs, frontal suture: Lbr, labrum: Ms, median suture: Cb, upper margin of clypeus. 115, *M. lecointei*. Labium and maxilla from below. 116, *M. carbonarius*. Part of labium and maxilla from above. 117, *M. metoecus*. Side view of larva. A, anus: Abl, abdominal lobes of abdominal segment I: C, clypeus: Dk, median dorsal knob of abdominal segment X: L, Labium: Lbr, labrum. Sp. 1, enlarged first spiracle: 1–10, abdominal segments: Th, 1, 2, and 3, thoracic segments.

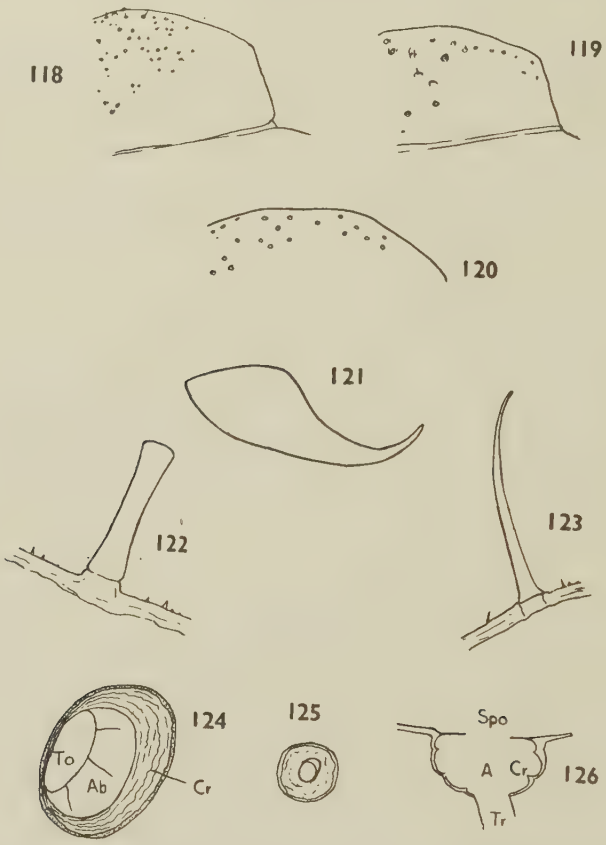
fashion as the spiracles of *Polistes*, *Nectarinia* and *Polybia*, already described. Fig. 126 is a side view of one of these small spiracles, drawn under higher power.

Mischocyttarus metoecus Richards.

Length about 9·0 mm.

This species is practically identical with *M. lecointei* (Ducke), but may be distinguished by the appearance of the sensory bristles upon the abdominal

lobes (see figs. 122, 123). Those of *M. lecointei* (Ducke) are of a normal shape, tapering to a point, but those of *M. metoecus* are short, stout, and expanded distally, and almost flat ended. This curious difference is the only one I have discovered between the larvae of these two species, but it is perfectly definite and distinct.



Figs. 118–126.—118–119. *Mischocyttarus carbonarius*. 118, Labrum; 119, Palate. 120, *M. lecointei* (Ducke). Labrum. 121, *M. oecothrix*. Mandible; viewed from the back. 122, *M. metoecus*. Sensory bristle from abdominal lobe, highly magnified. Cuticle seen in optical section. 123, *M. lecointei*. As for fig. 122. 124–126. *M. cerberus* var. *acheron*. 124, First thoracic spiracle. Ab, sloping floor of atrium: Cr, crenate ridges on atrial walls: To, tracheal opening; 125, Abdominal spiracle, to the same scale as fig. 124; compare figs. 60, 61 and 85; 126, Abdominal spiracle, side view. Optical section (more highly magnified than in fig. 125). A, atrium: Cr, ridges on atrial walls: Spo, spiracular opening: Tr, trachea.

Mischocyttarus cerberus Ducke var. *acheron* Richards.

Length about 9·0 mm.

Head: The distribution of brown and pale areas upon the head is similar to that of *M. lecointei* (Ducke), but the brown is not so dark or dense, being a smoky brown. In structure the head is the same as that of *M. lecointei*.

Body: The same as that of *M. lecointei*, except for differences in the abdominal lobes and the absence of any median dorsal knob on abdominal segment X. The abdominal

lobes (see fig. 129) are shorter than those of *M. lecointei*; they are parallel to one another and blunt ended, and the sensory bristles are not confined to the outer basal part of each lobe, but are distributed up the sides of the lobes and on the ends; the bristles are very pale.

Mischocyttarus synoecus Richards.

About 9·0 mm. long.

Head: Morphologically there is no difference from that of *M. lecointei*, but it is less sclerotised. The genae, particularly the lower parts, are dark smoky brown, the rest of the head capsule, including the clypeus and most of the upper half, is straw coloured, slightly darker on the clypeus than on the top of the capsule. The labrum and labium and maxillae are colourless; the mandibles are pale smoky brown and the papillae of the labium and maxillae light brown. Frequently there is a crescent-shaped dark band behind, and parallel to each temporal band; it can be seen to be composed of minute dots of pigment, but is probably sub-cuticular; as I cannot find it on the stained preparation of the head capsule, possibly it has something to do with the formation of the adult eye.

Body: The abdominal lobes are rather similar to those of *M. cerberus*, being parallel to one another and blunt ended; they are, however, rather shorter; the distribution of the bristles is similar, but they are dark brown instead of pale, being darkest towards the base of each lobe. The rest of the body is as described for *M. cerberus*.

Mischocyttarus oecothrix Richards.

About 10·0 mm. long.

Very similar to the preceding species with the following differences. The head is parti-coloured as in the preceding species but the pattern is different; the whole of the lower quarter of the head capsule is dark brown to black, being darker round the bottom of the head capsule. The upper boundary of this dark area runs from the sides of the head capsule, across the head at a level above the antennae, until a point just medial to the antennae is reached, when it dips sharply down to cross the clypeus at the level of the antennae. The crescent-shaped marks are present behind the temporal bands. The abdominal lobes are a little stouter and more blunt ended, and the bristles of the lobes are more numerous and are fine, long and rather pale smoky, compared with those of *M. synoecus*. Segment 10 of the abdomen is somewhat swollen.

Mischocyttarus carbonarius (Saussure).

Length about 14·0–15·0 mm.

Head: the head capsule is dark brown to pitchy, with pale areas at the top and on the frons. The labrum and mouth-parts are varying shades of smoky brown. Structurally the head is the same as that of *M. lecointei*, except that the sensillae upon the labrum are a little different (see fig. 118). There are obvious sensory bristles present, and the sensillae are of various sizes and are not confined to the anterior border of the labrum; the conditions in *M. lecointei* are the reverse of these.

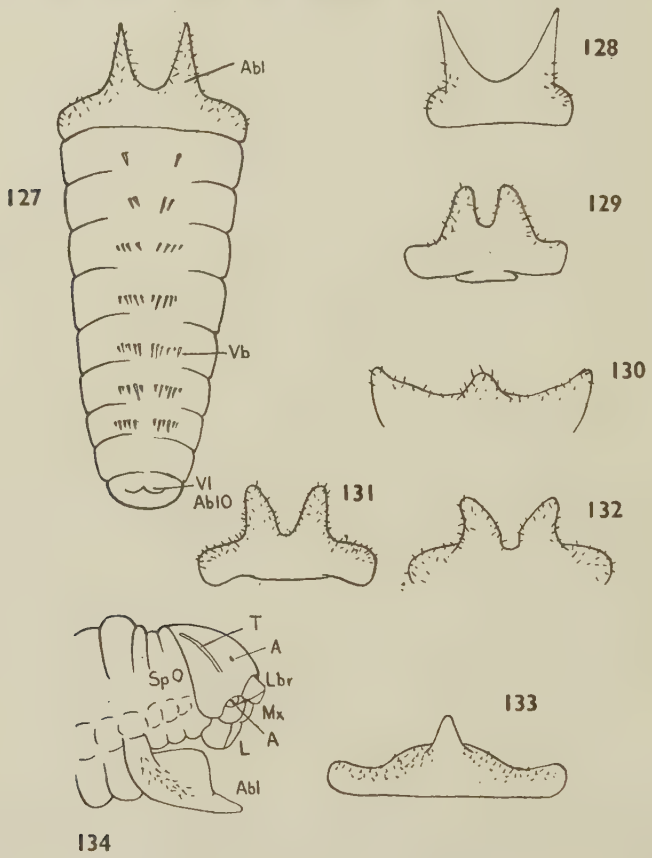
Body: There are three abdominal lobes instead of two (see fig. 130). They bear stout, dark bristles, and in addition, upon the outer face of the two exterior lobes, there is a short, thick, pale, pilosity. Upon the dorsal halves of the third thoracic, and first abdominal segments, are a few inconspicuous brown bristles. They are arranged on each of the two segments, in a median transverse row, interrupted in the mid-dorsal line and terminating on each side at the level of the spiracles. Upon segment IX of the abdomen in the same position, there is a similar single row of bristles. Upon the ventral surfaces of abdominal segments II–VIII inclusive, there are similar bristles; they rise vertically from the cuticle and are arranged on each segment, in two groups, disposed transversely, one on either side

of the mid-ventral line. There is a median dorsal knob on abdominal segment X, and the ventral lip of the anus is bifid.

Mischocyttarus collarellus Richards.

Length about 9·0–12·0 mm.

Head: The head capsule is smoky brown all over, slightly pale behind the temporal bands and with the median suture and antennae pale. The frontal sutures are faint.



Figs. 127–134.—127, *Mischocyttarus surinamensis*. Ventral view; semi-diagrammatic. Ab. 1 and Ab. 10; abdominal segments I and X: Vb, ventral bristles: Vl, ventral lip of anus. 128, *M. lecointei*. Abdominal lobes viewed as in fig. 127. 129, *M. cerberus* var. *acheron*. The same. 130–132, *M. carbonarius*. 130, Abdominal lobes viewed as in fig. 127; 131, *M. collarellus*. The same; 132, *M. superus*. The same. 133–134. *M. injucundus*. 133, The same; 134, Side view, to show abdominal lobe, etc. A, antenna: Abl, abdominal lobe: Ap, apodeme of mandible: L, labium: Lbr, labrum: Mx, maxilla: Sp, first spiracle: T, temporal band.

The labrum is mostly colourless, and the maxillary lobes and labium are also only partially coloured. The papillae are brown and the mandibles smoky brown, like the head and those portions of the mouth-parts which are coloured. The structural characters of the head are the same as those of *M. lecointei*.

Body: The thorax, as usual, resembles that of *M. lecointei*. The abdominal lobes (see

fig. 131) are of medium length, divergent from one another and round ended; there are fine, pale brown bristles, distributed over most of the lobes, except the posterior side of the base, from which the lobes arise, and this is bare in most species. The ventral surfaces of abdominal segments II–IX inclusive bear a few inconspicuous bristles arranged as described in *M. carbonarius*. There are no dorsal bristles and no knob on the dorsal half of abdominal segment X; the ventral lip of the anus is bifid.

Mischocyttarus Sp. 10.[3]

Length about 9·0 mm.

Head: The head capsule is a smoky brown with a pale area on each gena, behind and below the temporal bands, but not extending to the margin of the head capsule. The antennae, temporal bands, and median suture are pale. The anterior half of the labrum is irregularly smoky brown, only portions of the maxillary lobes and labium are brown, much as in the preceding species. Structurally the head is normal.

Body: The abdominal lobes are long and tapering, as in *M. lecointei* (Ducke), but do not terminate in such fine points, and are parallel to one another. The bristles and their distribution upon the lobes are similar to the condition described in the preceding species. There are some conspicuous bristles upon the ventral surfaces of abdominal segments IV–IX inclusive; they are arranged much as in *M. carbonarius* (Saussure), in a single transverse row upon each segment, each row being interrupted in the median ventral line and terminating before the lateral protuberances are reached. Unlike the condition in *M. carbonarius*, the bristles are thick, coarse, rather abruptly pointed and light fulvous brown, and instead of arising more or less vertically from the cuticle, they slope strongly towards the posterior end of the larva. The exact number upon each segment is variable, but there are 2–4 per segment on segments IV, V and VI, and 8–12 on segments VII, VIII and IX. On each segment there are about the same numbers of bristles on each side of the median line. The 10th abdominal segment is as described in the preceding species, though a little more prominent.

Mischocyttarus surinamensis (Saussure).

Length about 9·0 mm. Very similar to the preceding species.

Head: The coloration of the head is very similar to that of the species just described. The pale areas on the genae are a little more sharply defined and are rather larger, embracing the temporal bands and partially encircling the antennae. The shape is much the same, the outer edge being parallel to the margin of the head capsule, so leaving a border of brown round the edge of the head capsule, from its top round to the point where the lateral margins of the clypeus terminate on the anterior edge. The labrum, unlike that of the preceding species, is entirely colourless, as are the mouth-parts, except for the mandibles; the labrum is rather narrow and prominent.

Body: The abdominal lobes are like those of the preceding species, except that they taper to fine points and the bristles are a little coarser. There are bristles upon the ventral surface of the abdomen, like those of the preceding species, but they are borne on segments 2–8 inclusive instead of 4–9. As before, they are more numerous upon the hinder segments. It is noticeable that upon the forward segments, the bristles tend to point towards the median ventral line. The anal segment resembles that of the preceding species.

Mischocyttarus superus Richards.

Length about 9·0 mm.

Head: The head capsule is a dark smoky brown, the median suture, antennae and temporal bands paler. The labrum and mouth-parts are also brown, and the sensillae upon

[3] The single adult obtained from this nest is too immature to describe, but is closely allied to *M. surinamensis*.

the palate are rather conspicuous. Structurally the head is the same as that of *M. lecointei*.

Body: The abdominal lobes are rather short, strongly divergent and blunt ended (see fig. 132). The bristles upon them are pale coloured and distributed as shown in the figure, this distribution being similar to that in *M. collarellus*. The ventral bristles are the same as in the preceding species, and are present on segments 2–8. The ventral lip of the anus is bifid and there is no median dorsal knob on the anal segment.

Mischocyttarus injucundus (Saussure).

Length about 9·0 mm.

Head: The colouring of the head is similar to that of the preceding species, though the temporal bands and antennae are paler and the labrum is not so dark a brown. There are some conspicuous sensillae upon the palate. Structurally the head resembles that of *M. lecointei*.

Body: This species is distinguished by having only a single median abdominal lobe (see fig. 133). The bristles upon the lobe are short, fine, and pale brown and do not extend to the end of the lobe, which is pointed. The ventral bristles are of the same kind as in the previous three species; they are considerably deflected towards the median line, and directed backwards as before; they occur on segments II–VIII inclusive and are not much more numerous upon the rear segments than on the anterior ones. The anal segment is normal and has no median dorsal knob.

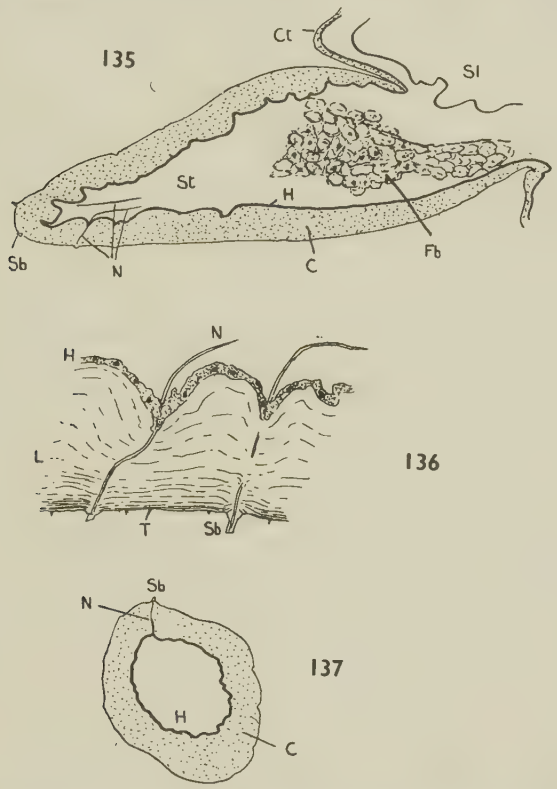
Conclusions.

It is evident from the foregoing descriptions that this genus is an extremely distinct one, having a number of characters which are very constant; for instance, the mandibles are always precisely the same, though they have always shown at least small variations in the other genera. The enlarged first spiracle is always present and the general structural features of the head capsule are extremely constant. Despite these characters, which show great constancy and lack of variability, there are a number of other ones, such as the presence or absence of bristles upon the venter and the shape of the abdominal lobes, which vary considerably and offer ready means of separating the species. These characters are all such as can be seen with a binocular microscope, or at the most the low power of the ordinary microscope, without the necessity of making slides; indeed it is somewhat useless to do so, for owing to the great constancy of the structural characters of the head, one could not separate the species by examination of the microscopic features of the head. It is because of this lack of variation in the structure of the head that I have figured the head of only one species, *M. oecothrix*, fig. 114.

The abdominal lobes (figs. 135–137).

The function of these structures is unknown. At first I thought they might be concerned with secreting substances attractive to the nurse wasps: that they were in fact examples of what W. M. Wheeler calls "exudatoria." On cutting sections it was found that the cuticle of these lobes is at least twice as thick as that of the adjacent parts of the thorax and abdomen, and frequently as much as ten times as thick, and since there are no pores leading through the cuticle of these lobes, it is highly unlikely that they serve any secretory function. There are no muscle fibres in these lobes, and they contain only fat body towards the base and an apparently structureless tissue in the upper part, through which nerves run to the sensory bristles. It is possible that these lobes act as a support for food, the nurse wasps placing it upon the lobes and the larva using

them as a kind of dining-table; this is known to occur in the larvae of certain bees which have lobes upon the ventral surface. The structure of the sensory bristles upon the lobes forms a slight support for this view, but of course direct observation of the feeding of the larvae in the nests would be necessary to prove it. The bristles, as the figures show, are each supplied with a large nerve, which appears to run up the inside of each bristle. Such sensory bristles, which have the nerves running up the inside of them instead of stopping at the



Figs. 135–137.—*Mischocyttarus* sp. 135, Median longitudinal section of an abdominal lobe. C, cuticle: Ct, cuticle of thorax: Fb, fat body: H, hypodermis: N, nerves leading to sensory bristles: Sb, base of sensory bristle: Sl, salivary gland: St, space occupied by structureless tissue; 136, Section of the cuticle of an abdominal lobe highly magnified. H, hypodermis: L, finely laminated structure of the cuticle: N, nerve supplying sensory bristle: Sb, part of sensory bristle up which nerve appears to run: T, non-sensory spinules, projections of the cuticle; 137, transverse section across an abdominal lobe, in the upper half. C, cuticle: H, hypodermis: N, nerve supplying sensory bristle, Sb.

base, are usually regarded as organs of taste, which is what one might expect to find upon external parts of the body with which the food commonly comes into contact. In view of the lack of muscle fibres in these lobes, the great thickness of the cuticle might well be an adaptation to keep them rigid and extended and capable of supporting weight and pressure. The structureless tissue in the ends of the lobes may be congealed blood, which in life would help to maintain rigidity. These lobes are rudimentary or absent in the young larvae.

Conclusions for the Polybiinae.

Unlike the subfamilies Vespinae and Polistinae, this subfamily comprises a collection of widely differing genera, which have only a few clear-cut characters in common. One meets both with success and failure when attempting to separate the genera and species; the genus *Mischocyttarus* is an easily distinguished genus, the species of which are readily separated; on the other hand, the genera *Polybia* and *Protopolybia* appear to be indistinguishable, though perhaps one could find means of separating them if more species were examined. It is almost certain that the other three genera, *Metapolybia*, *Stelopolybia* and *Nectarinia*, can be satisfactorily distinguished from one another, and I think that examination of more species of these genera would reveal diagnostic characters for each, though they might not be the same as those that I have made use of in the key. For reasons already explained, no generic characters are suggested for *Nectarinia*, but it is included in the key for the sake of completeness, the characters used being based upon the description of *Nectarinia scutellaris*.

Du Buysson (1906) described and figured the larvae of *Apoica pallida* (Olivier) and *Synoeca* sp. in the same fashion as that of *Nectarinia lecheguana* (Latreille). All that one can deduce from these figures and descriptions is that the larvae are of the Polybiine type; the lower margin of the clypeus not coming below the level of the bases of the mandibles (he showed it as doing so in *Nectarinia lecheguana*, but this is certainly an error), and the mandibles being circular in section, and in comparison with those of the Vespinae and Eumeninae, soft and slender. The mandibles of *Apoica pallida*, as figured, are similar to those of the genus *Polistes*.

In a monograph of the African Polybiine genus *Belonogaster*, du Buysson (1905) gave a description and two figures of the larva of a species of this genus; there is another drawing in a paper by Roubaud (1916). Unfortunately, practically nothing can be made out from the figures; one can see, however, that the mandibles are of the Polybiine type, and they are apparently rather similar to those of *Mischocyttarus*.

Discussion.

A few conclusions may be drawn from the results expressed in the foregoing pages. The first of these is that the larvae of the four subfamilies, Eumeninae, Vespinae, Polistinae and Polybiinae, can be clearly distinguished one from another. In other words, the characters of the larvae clearly confirm the existing classification deduced from the structure of the adults.

The second conclusion concerns the relationships of these subfamilies to each other. The evidence from larval characters seems to show that the Eumeninae and Vespinae are more closely related to one another than they are to the Polistinae and Polybiinae, which in turn are fairly closely related to one another. It may help if I summarise the characters that the members of each pair have in common, not forgetting that there are numerous differences as well. Considering first the Eumeninae and Vespinae: both have the lower margin of the clypeus ventral to the level of the bases of the mandibles. The mandibles in both are stout, angular in cross section, strongly sclerotised, and usually tridentate apically. In both the palate bears sclerotised patches in which are conical sensillae and the posterior margin of the palate is usually clearly defined. Sometimes the Vespinae show a slight development of the spinous

processes on the palate, characteristic of the EUMENINAE. The transverse ridge or lamina associated with the opening of the salivary gland, which is common in the EUMENINAE, is sometimes present in the VESPINAE. With regard to the POLISTINAE and POLYBIINAE, the lower margin of the clypeus, at least medially, is dorsal to the level of the bases of the mandibles. The mandibles are usually slender; they are circular in cross section and are but little sclerotised; frequently they terminate in a single slender, fine pointed tooth. Forked sensory bristles are commonly present upon the mouth-parts in both subfamilies.

The combination of all these characters in common seems to indicate a true affinity between the members of each of these pairs of subfamilies. Despite these evidences of affinity, the larvae of the EUMENINAE differ in a number of important respects from those of the VESPINAE, but this is not so in the case of the POLISTINAE and POLYBIINAE. Although the larvae of the POLISTINAE are easily recognised by their general appearance, the only really critical character for separating them from the POLYBIINAE is the presence of several sensory bristles behind each labial papilla, instead of only one. It is true to say that *Mischocyttarus* is more distinct in many ways, from the other Polybiine genera, than are the POLISTINAE from the POLYBIINAE as a whole.

Claude-Joseph (1930) gave a small figure of the head of the larva of *Zethus dicomboda* (Spinola) and of *Discoelius merula* Curtis, both of the subfamily ZETHINAE; the heads seem to resemble those of the larvae of the EUMENINAE; the clypeus and labrum are prominent and the mandibles are stout and tridentate.

I have shown that on larval characters the four subfamilies dealt with can be clearly separated from one another, but on the question of whether or not it is possible to distinguish the genera and species of Vespid larvae, the results do not give such an unequivocal answer. Of the four subfamilies considered, the POLYBIINAE is the only one of which there were larvae of a sufficient number of species and genera to form a fair test of how far these may be separated from one another. The results obtained with this subfamily, so far as one is justified in applying them to the other subfamilies, seem to show that most often one can separate both genera and species, but not always. Of the six genera represented in this subfamily, it seems that four can be satisfactorily distinguished and two cannot. Only in three of these genera were there larvae of more than one species, but in all three the species could be separated. It might of course be possible to construct keys to Vespid larvae in which two genera were dealt with as one, and yet all the species were distinguished.

Probably those genera in which the larvae have soft and colourless heads will prove the most difficult to tabulate. The various sutures and pits are very difficult to see, and the heads easily become crumpled when being mounted on slides; while the possibility of differentiation on colour markings is of course ruled out. It seems that the majority of the Polybiine genera have soft colourless heads, while the EUMENINAE, VESPINAE and POLISTINAE, particularly the first two, have well-sclerotised heads. On these grounds alone one would expect a greater measure of success in separating the genera and species of these three subfamilies than in separating those of the POLYBIINAE, and up to a point this probably would be so. To judge by the drawings, particularly those of Grandi, the EUMENINAE show plenty of possible specific characters, but generic characters might be harder to find. Much the same applies to the VESPINAE; the species could probably be distinguished, but the existing genera might prove difficult to separate. In ease of classification, the POLISTINAE

would probably prove to be intermediate between the EUMENINAE and VESPINAE on the one hand and the POLYBIINAE on the other.

The characters useful in classification call for some discussion. Only external characters have been used, but investigation of the internal anatomy of Vespid larvae might yield some useful characters.

In the section on the larva of *Polistes gallicus* (L.), I have discussed the question of using the distribution and numbers of the sensillae upon the mouth-parts as a means of separating species. The conclusion is that they are of little value, owing to the high degree of variability that their numbers and positions display within one species. Nevertheless they will probably be of some value in the future, if only on account of the various forms they assume. For example, the larvae of the EUMENINAE quite frequently have large sensillae of distinctive appearance upon the labrum; accurate drawings of these might serve to distinguish some of the species. Apart from these sensillae of the mouth-parts, which, with certain exceptions, have only a small value in classification, most of the other features of the body are of value. The relative positions and sizes of the various parts of the head capsule are of great value in separating the subfamilies; this is particularly true of the clypeus and labrum. The shape of the mandibles is rather characteristic of each subfamily, and the mandibles also yield generic and specific characters. The colouring of the head capsule and the size and abundance of the hairs upon it are sometimes useful specific characters. The width of the mentum, in comparison to the width of the labrum, is a useful generic character in the POLYBIINAE. The thorax and abdomen also provide useful characters, but with the exception of the genus *Mischocyttarus*, these are usually of less value than those of the head. The nature of the spiracles is of some value, particularly in the VESPINAE. The presence or absence of hairs or bristles is sometimes useful and assumes considerable importance in the genus *Mischocyttarus*. Finally the shape of the last or tenth abdominal segment, on which the anus opens, frequently has a limited use.

These characters suggest a few points to be borne in mind when examining larvae. When preparing the heads for examination, the mentum and maxillae should not be separated from the head capsule, at least at first, since, once separated, it is difficult to estimate any characters which involve comparison between parts of the head capsule and parts of the mentum and maxillae. When figuring any species, on account of the importance of the relative proportions of the parts of the head, a large-scale, accurate drawing of the whole head, viewed "full face," is very desirable. Although the positions and numbers of the sensory bristles and sensillae upon the mouth-parts are seldom important, there are exceptions to this, viz. :—the presence of only one sensory bristle behind each labial papilla in the POLYBIINAE and of several in the POLISTINAE. Also there are characters upon the mouth-parts which are unconnected with the sensillae; for example, the spinous processes upon the palate which are a feature of the EUMENINAE, the presence or absence of a ridge in connection with the opening of the salivary gland, and other characters. Thus it is still necessary to examine the microscopic structure of the mouth-parts. The age of a larva is a matter of considerable importance; as stated earlier, Peltrera found very considerable differences between a young larva of *Polistes gallicus* (L.) and adult ones taken from capped cells; Soika records differences between an adult larva of *Eumenes pomiformis* (Fabricius) and Grandi's description of a young larva of this species. I have found differences in this respect in the larvae I have examined. Evidently, wherever possible, larvae in their last instar, but not yet in the prepupal stage, should be used.

In conclusion, one may say that the classification of the larvae of the VESPIDAE, however interesting and illuminating it may be for its own sake, forms only a part of the much greater task of examining the comparative structure of all the families of aculeate Hymenoptera. The comparative description of aculeate larvae has, somewhat naturally, lagged behind that of the larvae of the Phytophaga and Parasitica, but a few of the main distinctions are slowly beginning to be apparent. Soika (1934) gave a tentative key to the larvae of a few families of aculeates.

The classification of aculeate larvae, in turn, is but a part of the wider task of comparing the structure of the larvae of the whole order Hymenoptera. When this has been accomplished, one may expect that one's understanding of the phylogeny of the order will have been greatly increased.

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NOTES ON THE GENUS *HELIOGOMPHUS* LAIDLAW, WITH DESCRIPTIONS OF TWO NEW SPECIES (ODONATA)

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Manuscript received 12.vi.1941.

Read 1.iv.1942.

With Plate 1 and Three Text-figures.

The genus *Heliogomphus* Laidlaw belongs to the subfamily Epigomphinae in which the distinguishing character is an increase in the cross neuration between the sectors of the arculus proximal to the level of the bifurcation of the Radial sector, the latter bifurcation being always more or less asymmetrical. This local increase in the cross nervures is unique, so that *Heliogomphus*, along with all other genera in this subfamily, must be considered as a comparatively modern product in the family Gomphidae. From the evidence afforded by the character of the male anal appendages, there is every reason to believe that *Heliogomphus* has been derived from either *Microgomphus* or *Macrogomphus*, and of these two, the relationship appears to lie closest to the former. In *Heliogomphus kelantanensis* (Laidlaw) the anal appendages are very simple and approximate to the conventional type found in *Gomphus*, so that in this species, unless there has been a reversion to type, the characters suggest that it lies at the base of the genus. Placed originally in *Gomphus*, it has been removed successively to *Leptogomphus* and then to *Heliogomphus*, which fact alone proves it to be a very aberrant species.

Both in *Microgomphus* and *Macrogomphus* the superior anal appendages are characterised by possessing an inner medial branch varying in length, shape and robustness in the species. It is this branch which has evolved into a robust corkscrew-like structure and has given the lyrate character to the combined superior anal appendages of *Heliogomphus*. This is clear if the appendages of a series of species be examined, beginning with those of *Microgomphus torquatus*, in which the branch of the appendage is thin and weak, and passing successively to *M. souteri*, where the branch is more robust and greatly elongated, or to *M. loogali*, where the branch is taking the outward curl of the apex as in *Heliogomphus*, and then on to *Heliogomphus retroflexus* in which the branch is now much more robust and has taken on the curled or corkscrew-like character common to the whole of the Heliogomphines save *kelantanensis*. In *H. retroflexus* it will be seen that the apex of the branch has replaced the true apex of the appendage, which is now seen as a robust subapical external spine. Hereafter, by examining a series of species, it will be seen that the true apex of the appendage becomes more and more obsolescent, first as a spine, then as an angulation which becomes flattened out, curved and finally absorbed into the general outline of the outer border of the appendage. Another feature will also be noticed, namely a small outer subapical spine which is already evident in some species of *Microgomphus*, such as *torquatus* and *souteri*. In *Heliogomphus* this spine becomes greatly exaggerated and reaches its maximum in species like *H. scorpio* and *H. lyratus*. This spine is present in *H. kelantanensis*, but the

inner branch is represented by a mere rudimentary spine. Complementary changes are also found in the shape of the inferior appendage, which is rectangular, shallowly or more or less deeply emarginate in *Microgomphus* and *H. retroflexus*, and broadly splayed at apical border, triangular and with its branches directed obliquely outwards so as to show from beneath the superior appendages in the rest of the Heliogomphines.

Venationally there is little difference to be found between *Heliogomphus* and *Microgomphus*, and the same might be said of *Macrogomphus* if allowance be made for the richer venation as a response to a larger and more heavily built insect.

The Heliogomphines are true jungle creatures and breed in the small tributaries of larger montane streams or often in mere seepages adjoining such streams. In this respect they resemble the Microgomphines, but are not given like these to rising to the neighbouring trees, preferring rather to settle on the surrounding herbage where their shagreen colouring harmonises with their surroundings and affords a certain measure of protection. They are distributed throughout the moister parts of India, Burma, Ceylon, Malaysia, Indo-China, Borneo and the Philippines.

The genus was created in the year 1922 by Laidlaw and included primarily but a single species. To this have been added since a number of species, which were either new to science or have been transferred from other genera, so that at the present time, including two new species described in this paper, the number stands at seventeen, and the genus has grown to one of the largest and most important in the Gomphidae.

Laidlaw chose as his type *Gomphus nietneri* Hagen, but the actual specimen from which he took the generic characters came from Assam and proved later to be an entirely new species which I described under the name of *Heliogomphus selysi*; this latter therefore becomes the genotype. *Gomphus nietneri*, which is known only from Ceylon, is, however, a true *Heliogomphus*. A list of the known species with their distribution and synonymy follows :—

1. *Heliogomphus promelas* (Selys).
   Gomphus promelas Selys, 1873. Nilgiri Hills, Cochin, Annaimallai and Travancore Hills, S. India.
2. *Heliogomphus ceylonicus* (Selys).
   Gomphus ceylonicus Selys, 1878. Ceylon.
3. *Heliogomphus nietneri* (Hagen).
   Gomphus nietneri Hagen, 1878. Ceylon.
4. *Heliogomphus kelantanensis* (Laidlaw).
   Gomphus consobrinus Laidlaw, 1902 (nom. preoc.).
   Gomphus kelantanensis Laidlaw, 1902.
   Leptogomphus kelantanensis Williamson, 1907. Malaysia.
5. *Heliogomphus retroflexus* (Ris).
   Leptogomphus retroflexus Ris, 1912. Tonkin.
6. *Heliogomphus scorpio* (Ris).
   Leptogomphus scorpio Ris, 1912. South China.
7. *Heliogomphus spirillus* (Fraser).
   Leptogomphus spirillus Fraser, 1922. Assam.
8. *Heliogomphus bakeri* Laidlaw, 1925. Philippines.
9. *Heliogomphus gracilis* (Kruger).
   Leptogomphus gracilis Kruger, 1898. Sumatra.
10. *Heliogomphus blandulus* Lieftinck, 1929. Borneo.

11. *Heliogomphus drescheri* Lieftinck, 1929. Java.
12. *Heliogomphus walli* Fraser, 1933. Ceylon.
13. *Heliogomphus lyratus* Fraser, 1933. Ceylon.
14. *Heliogomphus kalarensis* Fraser, 1934. Nilgiri Hills, S. India.
15. *Heliogomphus selysi* Fraser, 1934. Assam.
16. *Heliogomphus lieftincki* sp. n. Burma.
17. *Heliogomphus cervus* sp. n. Burma.

Key to species of genus *Heliogomphus*.

1. Antehumeral stripe confluent with the mesothoracic collar . . . . 2.
–. Antehumeral stripe separated from the mesothoracic collar . . . . 7.
2. Superior anal appendages simple, similar to those of genus *Gomphus* and without lateral spine . . . . . *kelantanensis*.
–. Superior anal appendages strongly curled apically and with a robust lateral spine . . . . . 3.
3. Only a single black stripe on sides of thorax . . . . . *drescheri*.
–. Two parallel black stripes on sides of thorax . . . . . 4.
4. Vesicle with two short robust spines projecting backwards over occiput *lieftincki*.
–. Vesicle without spines . . . . . 5.
5. Superior anal appendages with a robust subapical inner strongly curled branch which is supplanting the obtuse apex of appendage; inferior anal appendage with branches projecting straight backwards . . . *retroflexus*.
–. Superior anal appendages with original apex obsolete and replaced by a strongly curled inner branch which fades insensibly into the appendage; inferior anal appendage with branches widely divaricate . . . . . 6.
6. Superior anal appendages without external spine . . . . . *gracilis*.
–. Superior anal appendages with external spine . . . . . *bakeri*.
7. Sides of thorax immaculate . . . . . *blandulus*.
–. Sides of thorax with two black stripes . . . . . 8.
8. External spine of superior anal appendages of great size . . . . . 9.
–. External spine of superior anal appendages of moderate size . . . . 10.
9. External spine of superior anal appendages acuminate, directed straight outwards; superior humeral spot absent. Species confined to Ceylon . . *lyratus*.
–. External spine of superior anal appendages obtuse and directed backwards and ventrad; superior humeral spot present. Species confined to South China . . . . . *scorpio*.
10. Antehumeral stripes sinuous; superior humeral spot present; vesicle of female produced posteriorly into two long outwardly curved horns. Species confined to Burma . . . . . *cervus*.
–. Antehumeral stripe straight; superior humeral spot present or absent; female vesicle without horns (save in *promelas*) . . . . . 11.
11. Lateral spine of superior anal appendages followed posteriorly by a deep narrow notch; superior humeral spot absent . . . . . 12.
–. Lateral spine of superior anal appendages followed posteriorly at the most by a very shallow concavity; superior humeral spot present or absent . . 13.
12. Lateral spine of superior anal appendages obtuse, directed backwards; antehumeral stripes reduced to short oval spots; species confined to Ceylon *walli*.
–. Lateral spine of superior anal appendages acuminate, directed obliquely outwards and backwards; antehumeral stripes elongate ovals. Species confined to Bengal . . . . . *spirillus*.
13. Superior humeral spot absent; female with vesicle produced backwards into two long outwardly curved horns . . . . . *promelas*.
–. Superior humeral spot present; female vesicle simple . . . . . 14.

14. Superior anal appendages tapering gradually towards the apex, not angulated subapically. Species confined to Assam . . . . . *selysi.*
–. Superior anal appendages broadening towards the apex and with the outer margin strongly angulated . . . . . 15.
15. Outer margin of superior anal appendages bent at less than a right angle *kalarensis.*
–. Outer margin of superior anal appendages bent at a complete right angle . 16.
16. Face entirely black . . . . . *nietneri.*
–. Face traversed by a chain of three yellow spots at the level of the postclypeus *ceylonicus.*

(Note: In my key to *Heliogomphus* given in 1934, *Fauna British India, Odonata* 2: 324, I gave in error *ceylonicus* as without an upper humeral spot.)

Heliogomphus cervus sp. n.

Male. Abdomen 37 mm. Hind-wing 32 mm.

Head: labium dull brown, midlobe tipped with black; labrum glossy black marked with two transversely oval greenish-yellow basal spots; rest of head black save for the genae and a broad greenish-white stripe on the crest of frons. Occiput slightly excavate, with rounded or sinuous border, the vesicle rising as a steep curved ridge between the lateral ocelli and deeply excavate anteriorly. Prothorax black with a narrow anterior collar, a geminate dorsal spot and a postero-lateral one on each side of middle lobe, and a middorsal linear spot on the posterior lobe all greenish-yellow. Thorax black on dorsum, greenish-yellow laterally where the sutures are mapped out broadly with black. Dorsum with a narrowly interrupted mesothoracic collar, narrow slightly sinuous antehumeral stripes pointed at both ends and not quite meeting the mesothoracic collar or the antealar sinus, and a small triangular spot on the inner side of the upper part of the humeral suture all greenish-yellow. Legs black, anterior femora with a yellow stripe on the inner sides, armature as for genus. Wings hyaline, palely enfumed along the margins in old specimens; nodal index $\frac{10\text{–}17 \mid 16\text{–}10}{11\text{–}12 \mid 11\text{–}11}$, pterostigma poorly but definitely braced, blackish-brown, an occasional supplementary cubital nervure in fore-wings, only a single row of postanal cells in fore-wings, anal triangle 3-celled, the middle cell pentagonal in shape, other venational details as for genus. Abdomen black marked with yellow as follows:—segment 1 entirely so save for a subdorsal black spot on each side; segment 2 with a middorsal trilobate narrow spot extending the length of the carina, and a spot on each side of the oreillets and a small apico-lateral spot; segments 3 to 8 with the middorsal carina finely yellow, the former segment with a basolateral triangular spot on each side. Anal appendages of the usual generic lyrate shape: superiors greenish-yellow with base and apex of lateral spine blackish, this latter spine being directed outwards and of very robust character: the apices well curled and turning rather abruptly upward (figs. 2, 3), inferior appendage glossy black, its branches diverging at an angle of 45 degrees and projecting well out from beneath the superiors.

Female. Abdomen 37 mm. Hind-wing 35 mm.

Markings entirely similar to those of the male; venation rather closer and nodal index slightly higher; an occasional supplementary cubital nervure in the fore-wings as in the male; sculpture of occiput and vesicle highly specialised, the postero-lateral corners of the latter produced into long robust curved hornlike processes which project well over the occiput and which evidently interlock with the male inferior anal appendage (figs. 1, 3, 6). Anal appendages yellow, short, subcylindrical, obtuse at apex but produced outwardly as a short fine spine.

Distribution: Upper Burma. Described from a pair taken by Col. F. Wall at Maymyo, 4.vii.25. *Type* in my collection. The male anal appendages are closely similar to those of *H. selysi* Fraser but the lateral spine is directed more outwardly and the branches of the inferior appendage are shorter and more

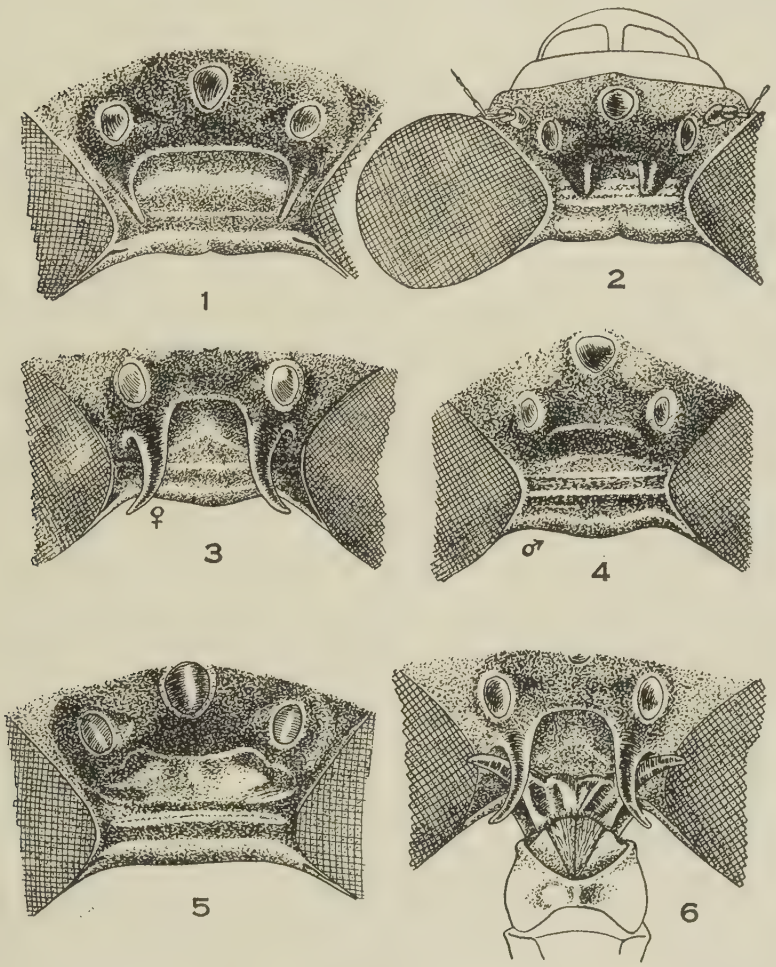

Fig. 1.—Occipital armature of: 1, *Heliogomphus promelas* (Selys), female. 2, *Heliogomphus lieftincki* sp. n., female. 3, *Heliogomphus cervus* sp. n., female. 4, male. 5, *Heliogomphus promelas* (Selys), male. 6, *Heliogomphus cervus* sp. n., female, showing the male anal appendages interlocked with the occipital armature of the female.

divergent. The sculpturing of the occiput and vesicle are also different, the antehumeral stripes are shorter and more divaricate and the upper humeral spot is absent. From other species, the shape of the anal appendages and the armature of the vesicle, especially of that of the female, will serve to distinguish this new species.

Heliogomphus lieftincki sp. n.

Female. Abdomen 30 mm. Hind-wing 27 mm.

Head: labium yellowish, apices of lobes black; labrum black, marked with two well-separated large subquadrate spots of greenish-yellow; anteclypeus, genae and a stripe across the crest of frons bright greenish-yellow. Occiput slightly convex but with a notch at its middle and a deep sulcus running transversely across it; vesicle rising steeply from the anterior ocellus to form a prominent ridge, the outer ends of which are produced into obtuse horns which do not, however, extend over the occiput and which are shorter and stouter than in *H. promelas* (Selys). Prothorax black, unmarked. Thorax black on dorsum, marked with a complete mesothoracic collar which is broadly confluent with rather broad antehumeral stripes which extend right up to the antealar sinus and form inverted yellow figures-of-7 with the collar; there is also a small triangular upper humeral spot of the same colour. Laterally greenish-yellow with two oblique black stripes on the sutures,

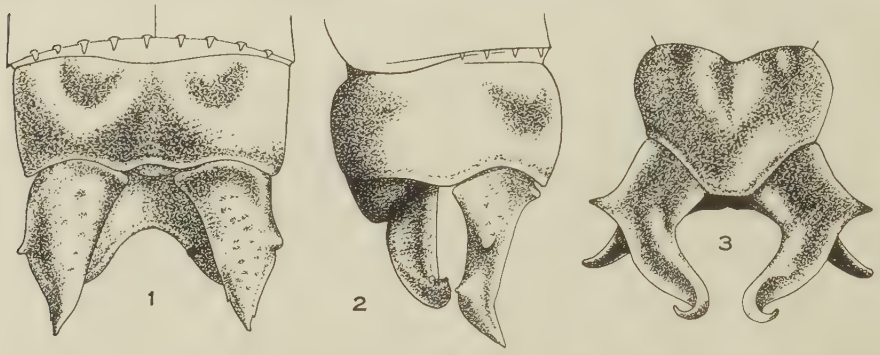

Fig. 2.—Terminal segment and anal appendages of: 1, *Heliogomphus kelantanensis* (Laidlaw), male, dorsal view. 2, The same seen from the left side. 3, *Heliogomphus cervus* sp. n., male, dorsal view.

the posterior of which is very narrow. Wings slightly tinted with yellow at bases; pterostigma yellow between thick black nervures; venation rather open, nodal index $\frac{11–15 \mid 15–11}{9–11 \mid 12–9}$. no accessory cubital nervures. Legs black, coxae yellow, armature as for the genus. Abdomen black, marked with yellow as follows: segment 1 yellow marked with a subdorsal quadrate black spot each side, segment 2 with a middorsal sagittate spot extending the whole length of carina and with the point of the arrow directed apicad; segments 3 to 7 with the middorsal carina finely yellow, whilst laterally a broad yellow stripe extends from segments 2 to 7, complete on segments 2 and 3 but broken by the jugal suture on the following segments. Vulvar scale very small, triangular and inconspicuous. Anal appendages yellow, shortly conical.

Distribution: Upper Burma. A single female taken by Col. F. Wall, 3.vi.25, the *type*, and now in my collection. The highly specialised character of the vesicle will at once serve to distinguish this species. This organ is produced into spines in both *H. promelas* and *H. cervus*, but in the former these are longer and finer, as well as widely separated, whilst in the latter they are much longer, more robust, curved and extend beyond the hinder border of the occiput. In these two species, also, the antehumeral stripes are well separated from the mesothoracic collar. The only other species known from northern India, *H. selysi* Fraser, has the vesicle simple and the antehumeral stripes and mesothoracic collar not confluent.

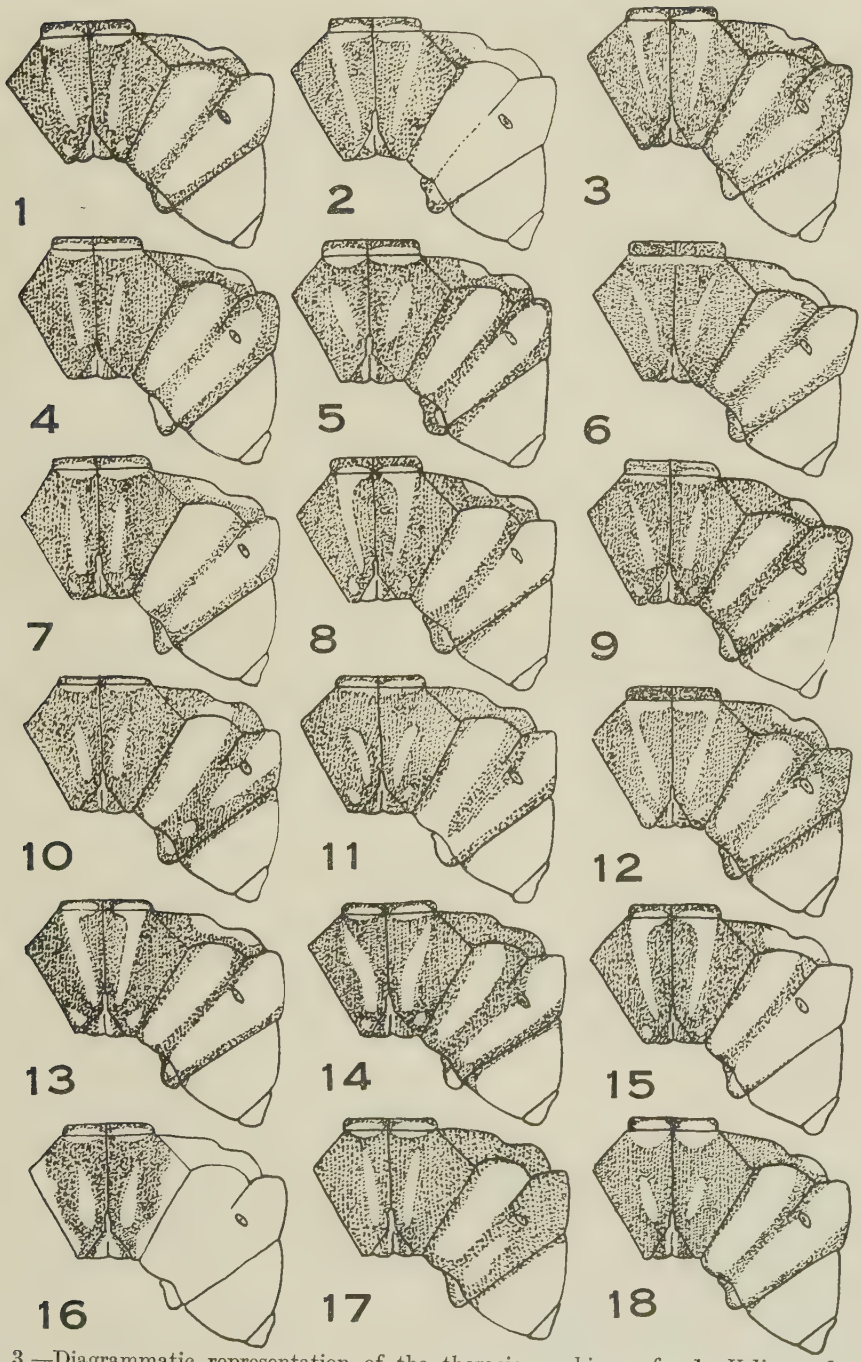

FIG. 3.—Diagrammatic representation of the thoracic markings of: 1, *Heliogomphus ceylonicus* (Selys). 2, *H. kelantanensis* (Laidlaw). 3, *H. bakeri* Laidlaw. 4, *H. promelas* (Selys). 5, *H. spirillus* (Fraser). 6, *H. retroflexus* (Ris). 7, *H. kalarensis* Fraser. 8, *H. gracilis* (Kruger). 9, *H. nietneri* (Selys). 10, *H. lyratus* Fraser. 11, *H. selysi* Fraser. 12, *H. scorpio* (Ris). 13, *H. lieftincki* sp. n. 14, *H. cervus* sp. n. 15, *H. drescheri* Lieftinck. 16, *H. blandulus* Lieftinck. 17, *H. promelas* (Selys), melanotic form. 18, *H. walli* Fraser.

Heliogomphus kalarensis Fraser.

Since the above was written, I have found the female of *H. kalarensis* Fraser, hitherto undescribed, among a number of duplicate specimens of *H. promelas* (Selys) which I was engaged in setting up. The specimen, a particularly large one, was labelled as belonging to the latter species but with a query. It was taken on the Kotagiri Ghat, Nilgiri Hills, S. India, a ghat which is separated from the Mettupalayam Ghat by a spur of the Nilgiris rising to 6000 ft. Kalar, where the type of *H. kalarensis* was taken, lies at the foot of the latter ghat not far from where the two ghats part company. Only two species of *Heliogomphus* have been taken in the Nilgiris in five years' continuous collecting, and as the female of *H. promelas* is well known, there can exist little doubt but that this female belongs to *H. kalarensis*, with the male of which it agrees closely. The description follows :—

Female. Abdomen 42 mm. Hind-wing 37 mm.

Markings closely similar to those of the male; the yellow point on occiput confined to the posterior aspect of that structure; the upper humeral point almost obsolete; the antehumeral stripes just meeting the mesothoracic collar. Wings palely tinted with yellow at bases; pterostigma dark ochreous between thick black nervures, braced in three wings only; venation similar to the male but nodal index slightly higher. Markings of abdomen similar to male but baso-lateral spot on segment six larger and more conspicuous. Anal appendages black, shortly conical. Vertex of head without the two conspicuous long horns found in *H. promelas*, these being represented by two inconspicuous tubercles.

Distribution :—S. India : Kotagiri Ghat, Nilgiri Hills, 9.vii.1933 (*F. C. Fraser*). This allotype female is in my own collection at present but, like all other types in this collection, will be deposited eventually in the British Museum. It is to be distinguished from *H. promelas* by the absence of the horns on vertex of head, this latter species being the only other one found in S. India.

The present paper offers a suitable opportunity for correcting some synonymy in the family Gomphidae :—

Gomphus abditus Needham = *Gomphus amnicola* Walsh **syn. n.**

Onychogomphus ardens Needham = *Onychogomphus camelus* Martin **syn. n.**

To the genus *Lamelligomphus* should now be added the following species placed in genus *Onychogomphus* :—*O. camelus* Martin, *O. ringens* Needham, *O. ridens* Needham, *O. micans* Needham, *O. ludens* Needham and *O. formosanus* Oguma.

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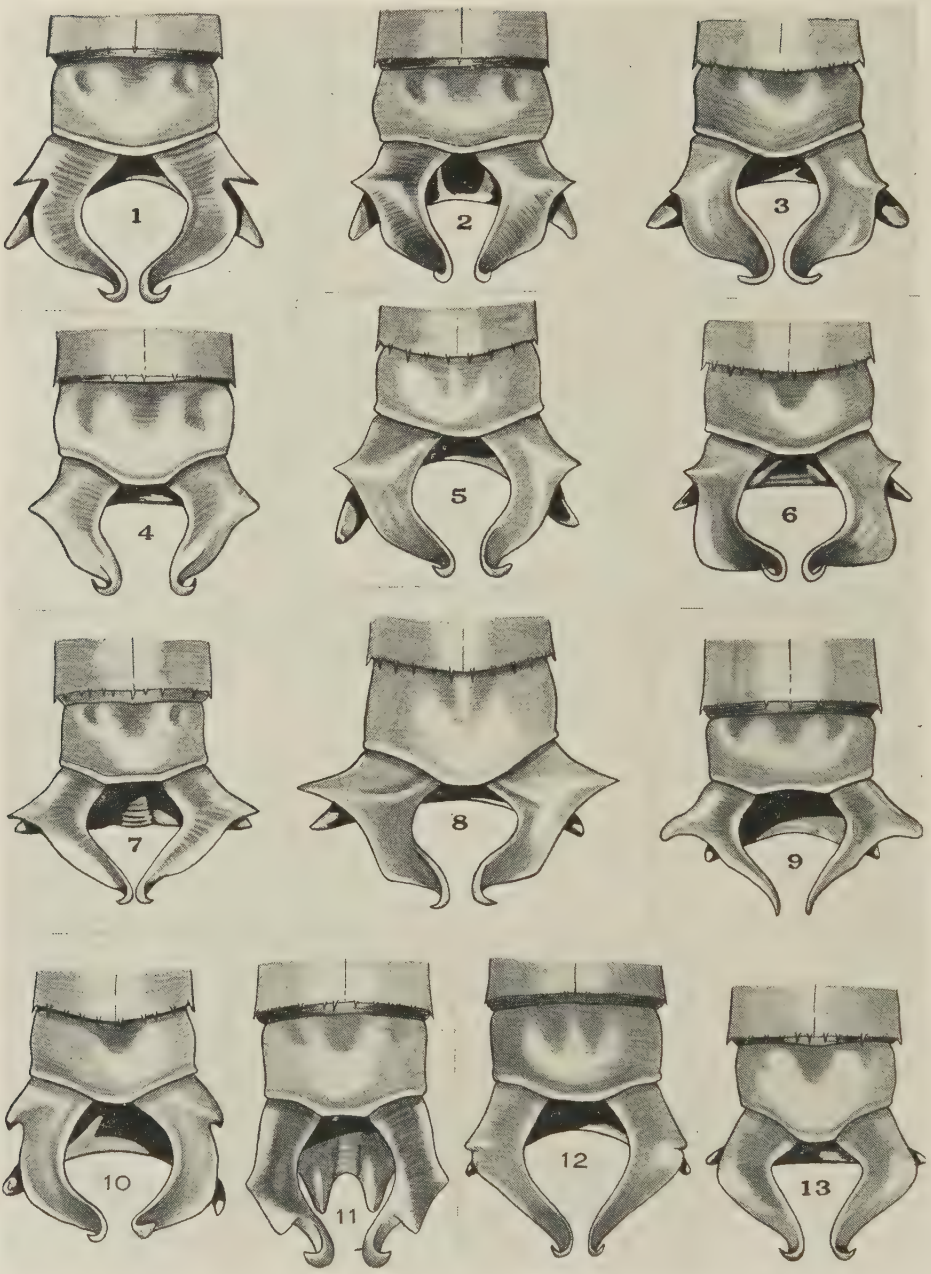

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Terminal segment and male anal appendages in **Heliogomphus.**

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Explanation of Plate 1.

Terminal segment and male anal appendages of : 1, *Heliogomphus spirillus* (Fraser). 2, *Heliogomphus promelas* (Selys). 3, *Heliogomphus kalarensis* Fraser. 4, *Heliogomphus blandulus* Lieftinck. 5, *Heliogomphus selysi* Fraser. 6, *Heliogomphus nietneri* (Selys). 7, *Heliogomphus drescheri* Lieftinck. 8, *Heliogomphus lyratus* Fraser. 9, *Heliogomphus scorpio* (Ris). 10, *Heliogomphus walli* Fraser. 11, *Heliogomphus retroflexus* (Ris). 12, *Heliogomphus bakeri* Laidlaw. 13, *Heliogomphus gracilis* (Kruger).

CHINESE TRICHOPTERA : A COLLECTION MADE BY MR. M. S. YANG IN FOOCHOW

By Martin E. Mosely.

Manuscript received 9th October, 1941.

Read 6th May, 1942.

With Fifty-seven Text-figures.

An extensive collection of Trichoptera made by Mr. M. S. Yang in Foochow, and sent to the Imperial Institute of Entomology, is of considerable interest. Good series of many species were secured, in one, no fewer than 349 examples, and, altogether, the collection totalled 708 specimens.

Four genera, *Apatidelia*, *Chimarrha*, *Pseudagapetus* and *Pseudoneureclipsis*, are new to the Chinese fauna, the first being new to science. It should be added that though new to China as now politically constituted, *Chimarrha* has been recorded in Formosa.

Of the 37 species listed in this paper, 19 are new to the Chinese fauna and of these 14 are new to science. A single female *Pseudoneureclipsis* and a *Rhyacophila* without abdomen are left undetermined beyond the genus, and perhaps attention should be drawn to some uncertainty in the determination of *Diplectrona melli* Ulmer, of which only females are present.

The material, with all types and paratypes of new species, has been kindly presented to the British Museum by the Imperial Institute of Entomology, and is now incorporated in the Museum collection. The locality, in every case, is the vicinity of Foochow, and the only dates available, except in a few particular instances which are indicated, are the years 1935–1936, 1936–1937.

Limnophilidae.

Apatidelia gen. n.

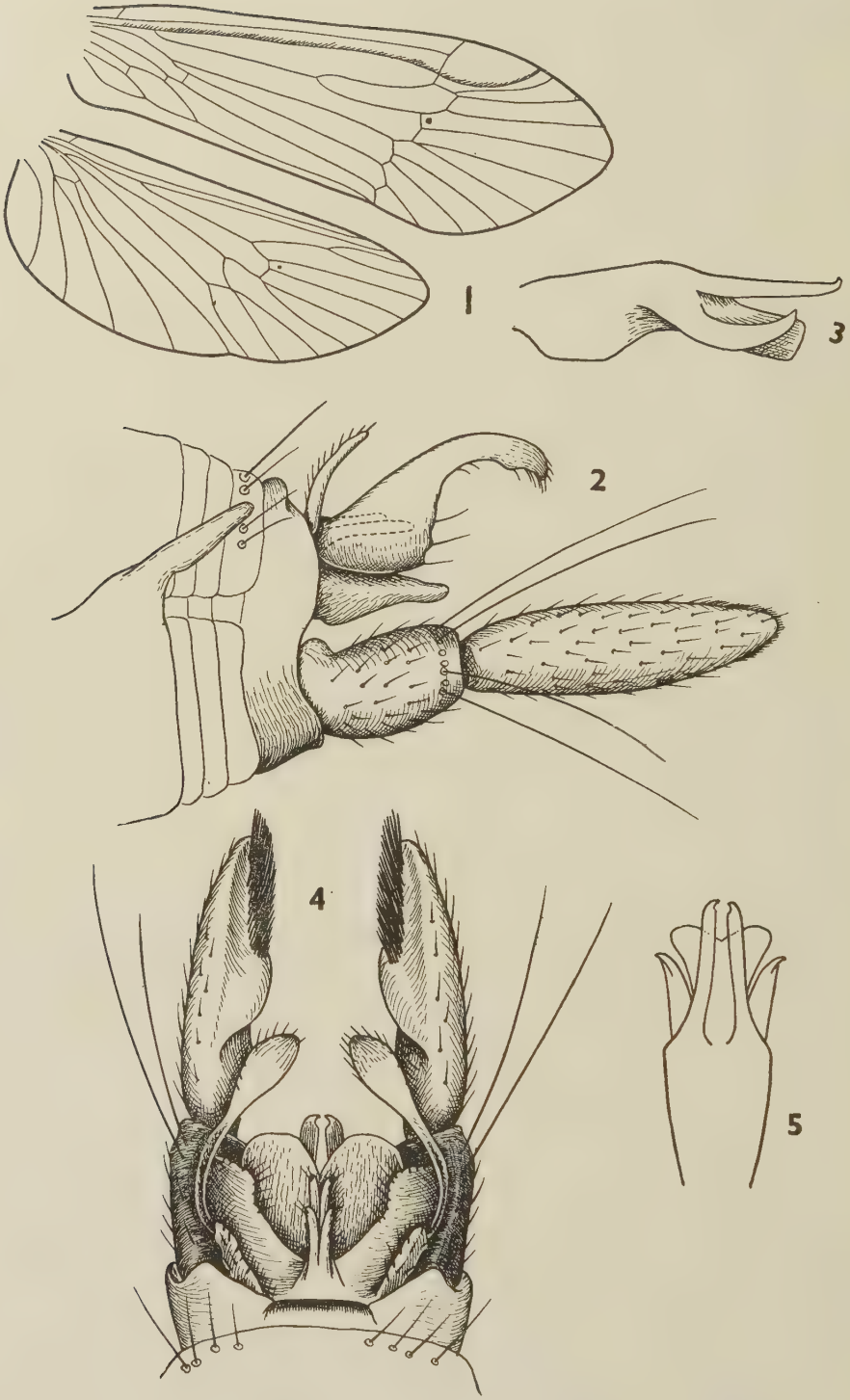
The genus differs from *Apatidea* in the posterior wing where the radius is not confluent with the subcosta towards its extremity. It differs from *Apatania* in having superior appendages, and from both these genera in possessing lateral processes arising from the 5th abdominal segment. Such processes, although frequently present in other genera, have been hitherto unknown in the Limnophilidae, though Betten mentions that the American genus *Allomyia* is characterised by the presence of a retractile filament in a similar position in the male sex only. The processes of *Apatidelia* do not have the appearance of being retractile. Spurs 1, 2, 4.

Genotype, *A. martynovi* sp. n.

Apatidelia martynovi sp. n. figs. 1–5.

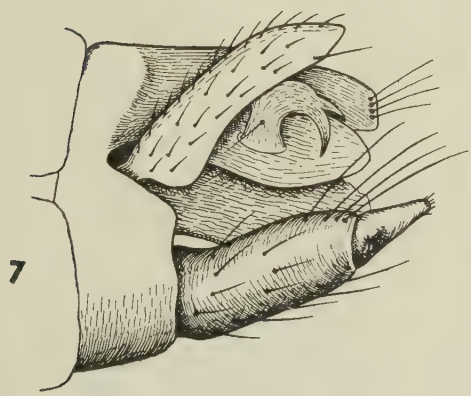
Insect nearly black; anterior wings dark brown; radius lined with a row of close, short, very black hairs from the apex nearly to the base; distal portion of the radius almost confluent with the 1st apical sector; in the posterior wing there are some long, black hairs lining the media.

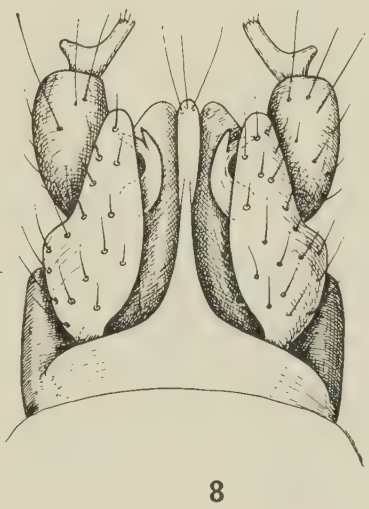
Genitalia ♂.—Apical margin of the 8th tergite bearing a group of four stiff hairs at each side; apical margin of the 9th tergite, widely excised with a short, strongly pigmented bar along its centre; superior appendages short, slender, strongly chitinized, slightly curved



FIGS. 1–5.—*Apatidelia martynovi* sp. n. ♂. 1. wings; 2. genitalia lateral; 3. penis, lower processes of the upper penis-cover and sheaths lateral; 4, genitalia dorsal; 5. penis, lower processes of the upper penis-cover and sheaths dorsal.

and directed upwards; intermediate appendages large, base concave with the lower basal margin strongly dilated; midway the appendage is constricted and the apices are dilated, twisted over and slightly inturned; arising between the bases of the appendages are two pairs of short processes, closely adpressed, the upper the shorter; there is an upper penis-cover in two parts, the upper membranous with an excised apical margin, the lower consisting of a pair of strongly chitinized rods with inturned, hooked apices nearly touching each other; penis with a widely excised apical margin and a pair of strong, straight sheaths, widely divergent at their apices; inferior appendages two-jointed, very long, basal joint half the length of the terminal joint which bears a mat of coarse, black bristles on its inner





FIGS. 6–8.—*Psilotreta ochina* sp. n. ♂. 6. wings; 7. genitalia lateral; 8. dorsal.

surface at the apex; there is a pair of large, fleshy lateral processes arising from the 5th segment; attached to the base of each process, within the walls of the abdomen, is a membranous sac.

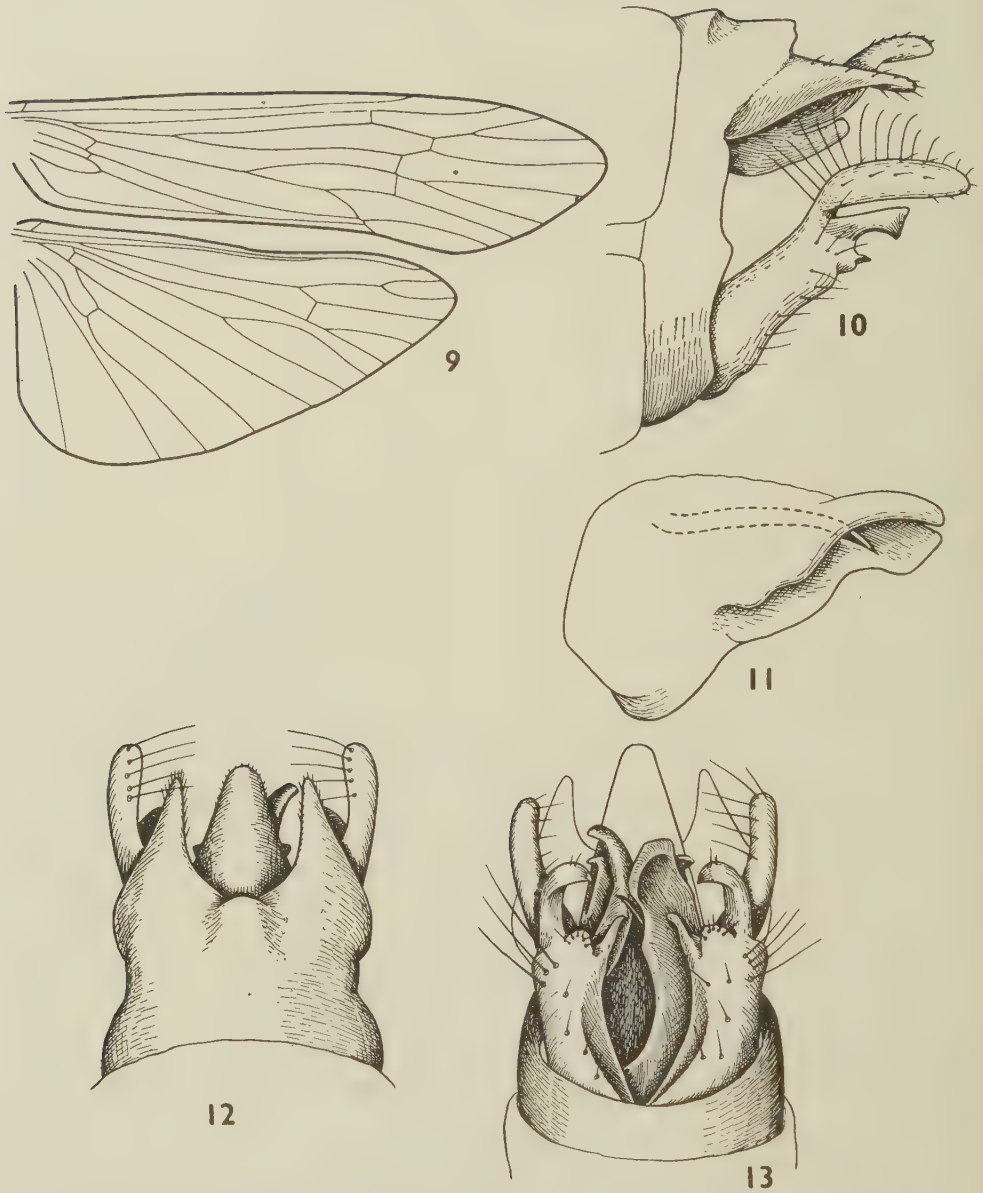
Length of the anterior wing ♂ 7 mm.

ODONTOCERIDAE.

Psilotreta ochina sp. n. figs. 6–8.

Insect yellowish all over with the exception of the oculi and thorax which are dark.

Genitalia ♂.—Apical margin of the 9th tergite produced in a long, slender process tapering from a wide base to a slightly dilated but slender apex armed with a few bristles; the process is deep from the side; on each side are the superior appendages, leaf-shaped,



FIGS. 9–13.—*Leptocerus inchinus* sp. n. ♂. 9. wings; 10. genitalia lateral; 11. penis and lower penis-cover lateral; 12. genitalia dorsal; 13. ventral and slightly from behind.

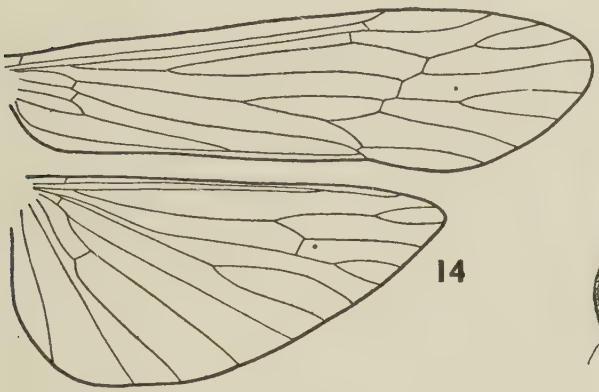
broad at the base where the outer margin is slightly produced; upper penis-cover wide both from above and from the side, apical margin cleft at its centre, upper surface furnished on each side with a stout, curved spine, bifurcate at its apex; penis straight, with a membranous and excised apex; inferior appendages two-jointed, basal joint long and stout, terminal short, shoe-shaped, sole directed distally, heel well defined, short, toe pointing inward with a truncate and strongly serrate apical margin.

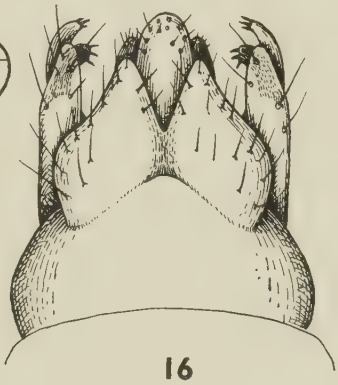
Length of the anterior wing ♂ and ♀ 6 mm.

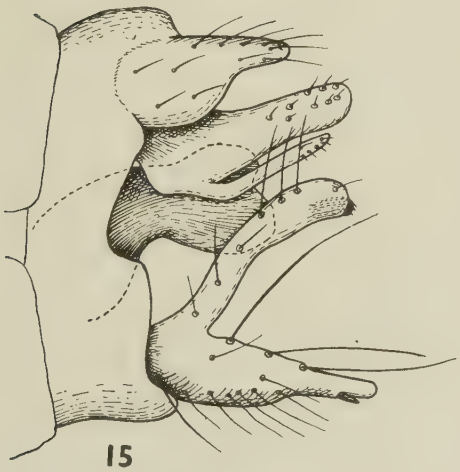
LEPTOCERIDAE.

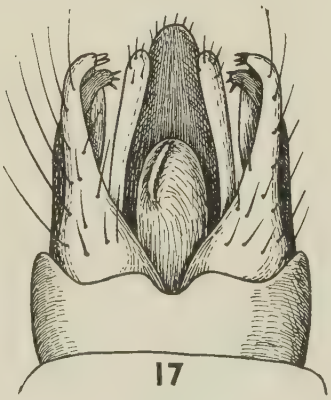
Leptocerus inchinus sp. n. figs. 9–13.

General appearance tawny-brown. Head and basal joints of the antennae clothed with dense and rather coarse, greyish-white hair, remaining joints strongly annulated with wide rings of white hair, covering about a third of the length of each joint at its base; palpi and legs dark ochraceous, covered with greyish-white hair; anterior wings tawny, sparsely clothed with short, white hairs; pterostigma well defined and extensive, forming an inverted, triangular patch with a wide base on the costa, and the apex covering the cross-









FIGS. 14–17.—*Leptocerus yangi* sp. n. ♂. 14. wings; 15. genitalia lateral; 16. dorsal; 17. ventral.

vein closing the discoidal cell; the two lower cross-veins of the anastomosis in line as in the European species *fulvus*.

Genitalia ♂.—Apical margin of the 9th tergite produced at its centre in a small, raised triangle, angles produced in large, triangular plates with produced slender apices; in the aperture between these plates, from above, is a large, conical upper penis-cover beneath which is a pair of stout penis-sheaths (?) with angular apices directed slightly outwards, from beneath; penis forming a down-curving and acute spine; lower penis-cover asymmetrical, consisting of a pair of down-curving processes of which the apex of one is acute

and the other a broad and rather shapeless plate; inferior appendages trifurcate, the first and upper fork long, curving slightly downward, fringed with widely spaced hairs on its upper margin; the second fork shorter than the first, apex hooked inward; the third fork the shortest, appearing as an inwardly-directed spur arising from the inner margin of the second.

Length of the anterior wing ♂ 14 mm.; ♀ 12 mm.

Leptocerus yangi sp. n. figs. 14–17.

The type is not in a condition fit to allow of a description of its external appearance and has now been mounted in balsam.

Genitalia ♂.—Apical margin of the 9th tergite produced in a pair of triangular plates with acute apices and rounded outer margins, bulging towards the base; beneath these is a large, conical upper penis-cover, deep at the base from the side and curving slightly upwards; under each lateral margin of the cover is a slender, upwardly directed process; penis short, stout, apex, seen from behind, appearing as a pair of parallel plates, two large spines concealed within it near the base; inferior appendages trifurcate, upper fork long, rather wide and membranous, dilated at the apex from the side, with a small and more strongly chitinized branch arising towards the apex and with a small, heavily fringed shelf situated on the inner margin near the base; the lower or third fork nearly as long as the upper, stouter and sparsely fringed with long hairs, apex inturned and toothed; apical margin of the 9th sternite excised at its centre.

Length of the anterior wing ♂ 8 mm.; ♀ 7 mm.

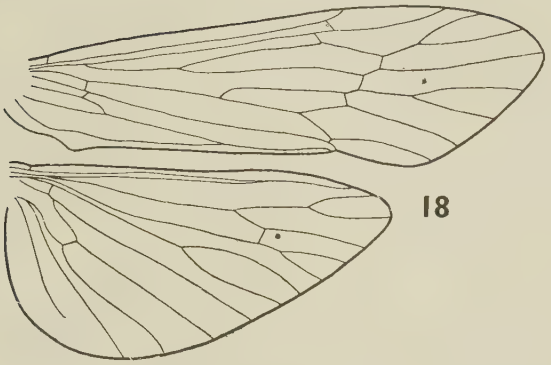
I have pleasure in dedicating this species to Mr. M. S. Yang, whose extensive collections in the Foochow district have provided many additions to the British Museum collections.

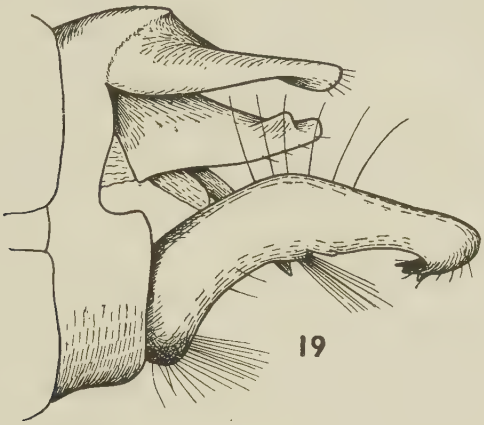
Leptocerus fooensis sp. n. figs. 18–21.

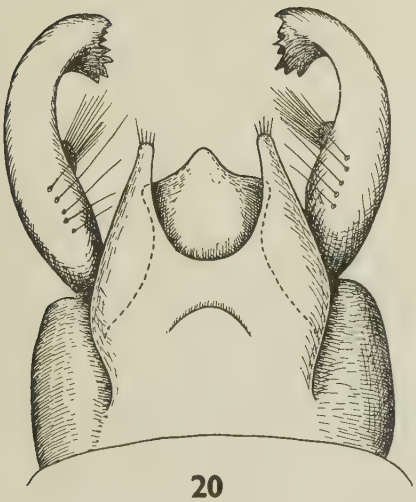
In a series of seven examples, there is a slight variation in the appearance of the wings, possibly owing to partial denudation. In the best preserved example, the anterior wings are of a rich, reddish-brown hue with a small dark patch at the distal, lower border, spreading into the fringe. In the more denuded specimens, there is an indistinct, dark speckling over a pale reddish-grey ground. Head and basal joint of the antenna clothed with white hairs, remaining joints fawn-colour conspicuously ringed with white at the base of each joint; palpi fulvous; legs clothed for the most part with dense and short white hair excepting the fore-legs where the white hairs are conspicuous only in small patches at the base of each joint.

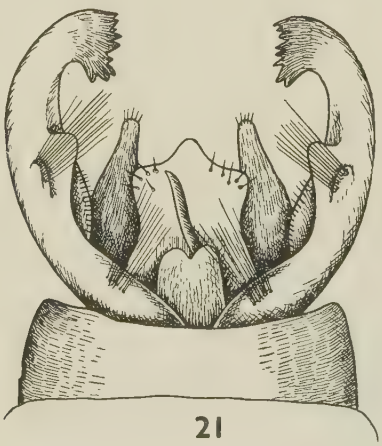
Genitalia ♂.—9th tergite produced at its centre in a small raised triangle beneath which is a broad plate with a round excision in its apical margin to leave a pair of wide, triangular processes with acute apices; in the excision may be seen the upper penis-cover which is broad, produced slightly at the centre of its apical margin; penis slender, strongly chitinized, arching slightly downwards; lower penis-cover spatula-shaped with an excision at the centre of its apical margin; inferior appendages unbranched, apices truncate and very serrate, inturned, with the lower angle produced downwards to enclose a rounded excision between itself and the main stem; at the base of the excision there is a small wart, or process with a second, still smaller, by its side; upper inner margin projecting towards its centre over the lower to form a narrow shelf; inner margin fringed with widely spaced hairs; a thick tuft of hairs on the inner under margin at the base and another at about midway; these tufts are very conspicuous in the dried insect.

Length of the anterior wing ♂ 9 mm.; ♀ 7 mm.









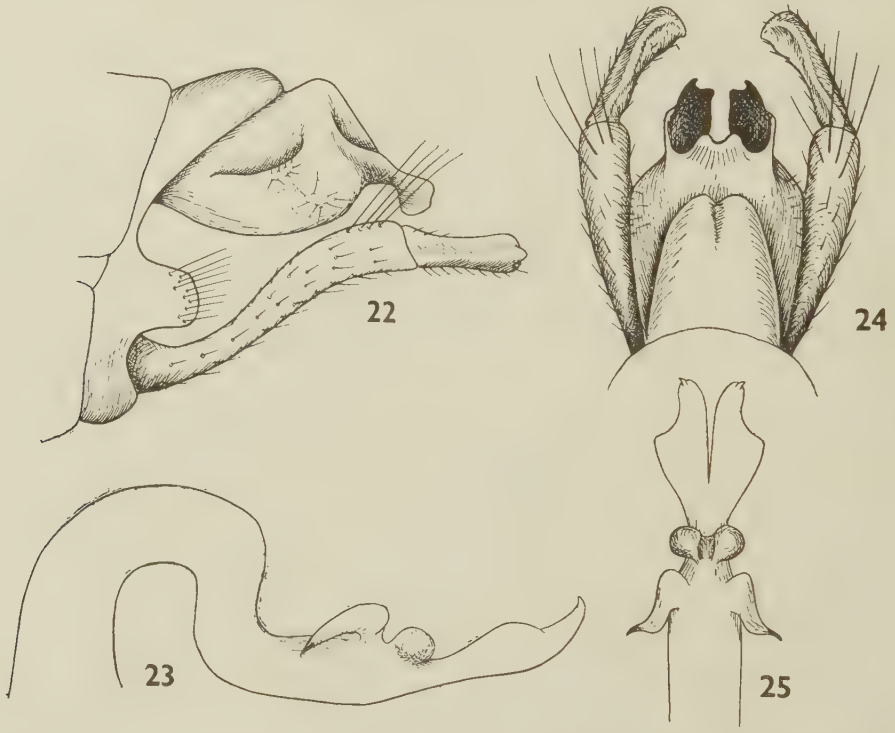
FIGS. 18–21.—*Leptocerus fooensis* sp. n. ♂. 18. wings; 19. genitalia lateral; 20. dorsal; 21. ventral.

HYDROPSYCHIDAE.

Hydropsyche simulata sp. n. figs. 22–25.

Insect with dark, reddish-brown wings. Antennae pale, with very conspicuous brown annulations but without the usual diagonal stripe.

Genitalia ♂.—Terminal tergite ending in a thimble-shaped projection with a central dorsal furrow and an excised apical margin; beyond this is a large dorsal plate, very deep from the side, with the distal end divided in a pair of rectangular, downsloping processes with concave upper surfaces and truncate apical margins of which the outer angles are



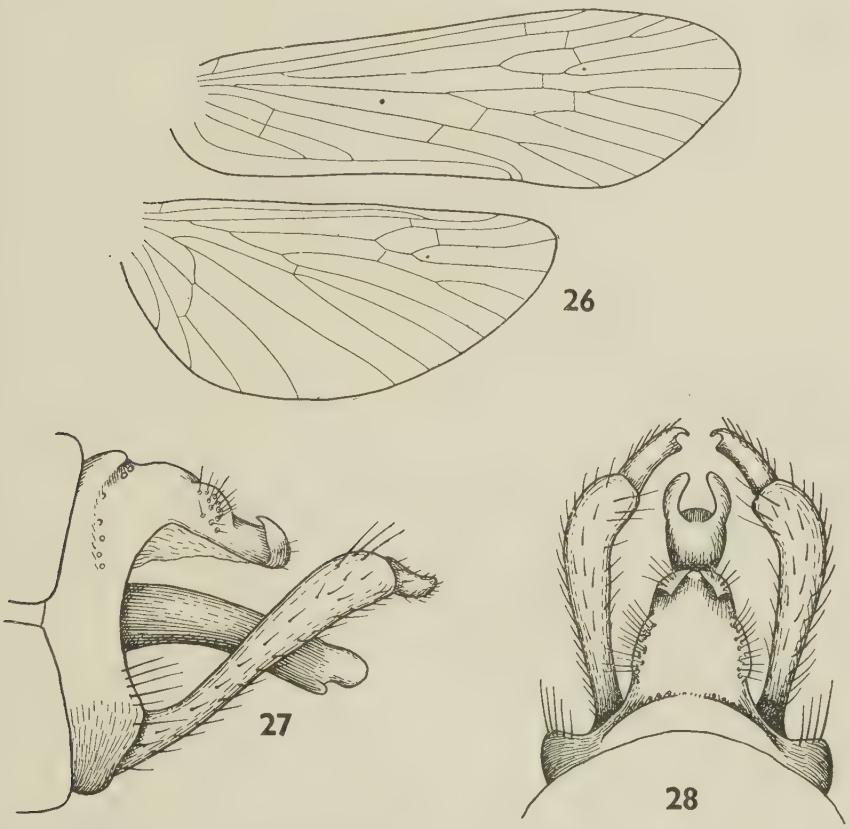
FIGS. 22–25.—*Hydropsyche simulata* sp. n. ♂. 22. genitalia lateral; 23. penis lateral; 24. genitalia dorsal; 25. penis dorsal.

slightly produced and hooked; from beneath, the apices are seen to be broad, flat and somewhat star-shaped; from the side, there is a rounded excision in the under margin to leave a dilated apex; side pieces of the 9th segment rectangularly produced and fringed; penis with the apex much dilated, the apical margin deeply cleft, each side narrowly produced to terminate in a small hook; below the apex, the stem is constricted and at this point is a pair of brown, rounded nodules near which arises a pair of membranous processes directed basally along the shaft of the penis and terminating in small, strongly chitinized spurs directed outwards; inferior appendages two-jointed, terminal about half the length of the basal joint with the apex dilated, apical margin truncate.

Length of the anterior wing ♂ 7 mm., ♀ 9 mm.

The species described above closely resembles Martynov's *H. valvata*, recorded from Semipalatinsk, southern Siberia. It differs in the following

points. The wings of *valvata* are pale and clothed with yellowish hair. Those of *simulata* are darkish brown. In *valvata*, according to the figure, the processes of the dorsal plate have acute apices, directed distally. In *simulata*, the apices are truncate and the processes are directed downward. In *valvata*, the apex of the penis is rounded. In *simulata*, it is deeply cleft and, from the side, produced and acute. In *valvata*, the terminal joint of the inferior appendage has an acute apex, that of *simulata* has a truncate apex.



FIGS. 26–28.—*Cheumatopsyche banksi* sp. n. ♂. 26. wings; 27, genitalia lateral; 28. dorsal.

Cheumatopsyche banksi sp. n. figs. 26–28.

General appearance characteristic of the majority of *Cheumatopsyche* species, namely, pale brownish, with faintly irrorated wings, the pterostigma being unusually strongly indicated, particularly when viewed by transmitted light. In the denuded anterior wing, various brownish streaks are apparent, one covering the middle of the radius and extending downward towards the base of the discoidal cell, another bordering the cubitus, which shows as a white line through it, a third covers the entire region about the anal veins, extending into the post-costal area.

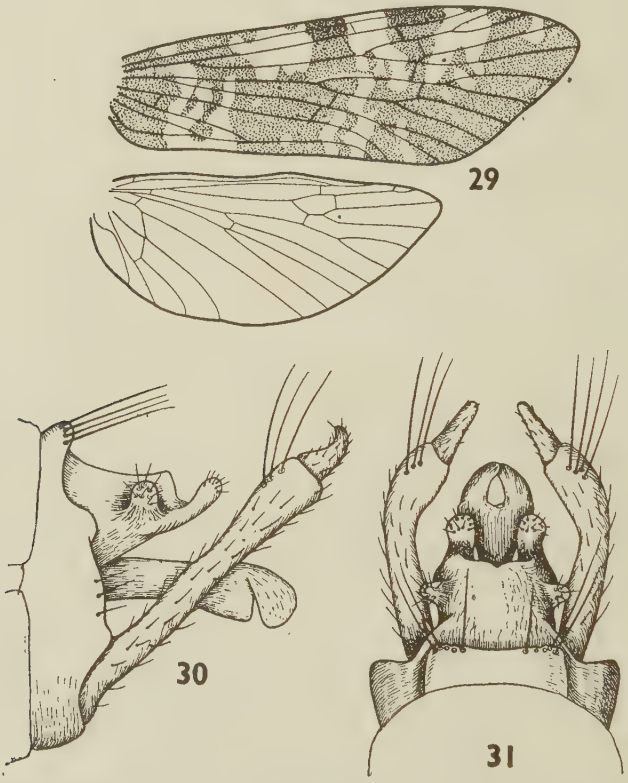
Genitalia ♂.—Apical margin of the 9th tergite produced and sparsely fringed with stiff hairs which continue round the tergite; dorsal plate tapering slightly to a blunt apex, a pair of hairy warts about midway, extending down over the lateral border; apex bifurcate

and turned back over the plate so that there is a small, hooked spur, as seen from the side: penis scarcely dilated at the apex which is widely bifurcate; inferior appendages two-jointed, terminal joint very short, apex acute and hooked inwards to leave a rounded excision.

Length of the anterior wing ♂ 9 mm., ♀ 8 mm.

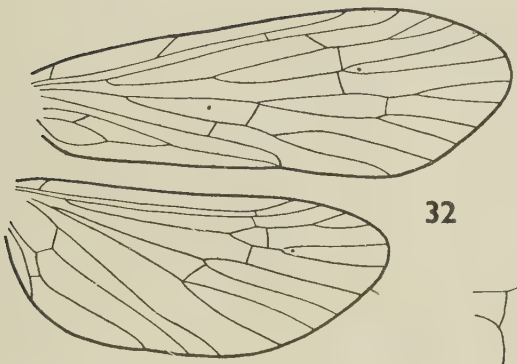
Cheumatopsyche dubitans sp. n. figs. 29–31.

This species forms an exception in the genus inasmuch as it has the anterior wings strongly patterned in brown and pale yellow. As indicated in the figure, the wing is



Figs. 29–31.—*Cheumatopsyche dubitans* sp. n. ♂. 29. wings; 30. genitalia lateral; 31. dorsal.

generally dark with three conspicuous pale patches extending from the costa half-way across the wing, with further indeterminate markings, particularly one towards the base, extending upwards from the lower margin and another beneath the central patch which it practically meets to form a band across the wing. Neuration as is usual in the genus except for the presence of a small fork No. 1 in the posterior wing. As the absence of this fork is not completely constant in *Cheumatopsyche*, I do not consider that its presence in this species and the unusual colour constitute sufficient grounds for the erection of a new genus. Head dark, oculi nearly black; antennae pale with a slight indication of a diagonal streak on the basal joints as found in *Hydropsyche*; palpi ochraceous; legs ochraceous with brown patches.



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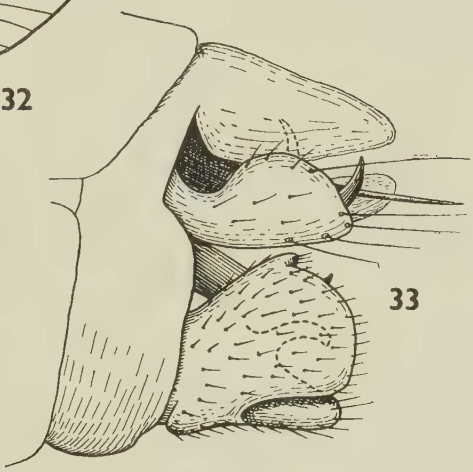

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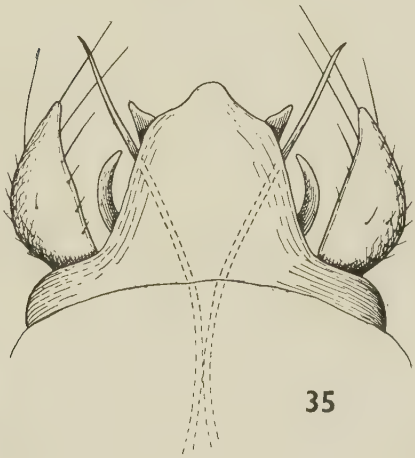

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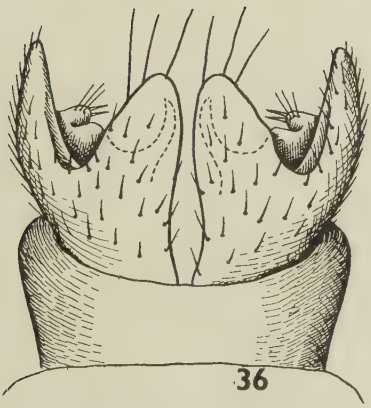

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FIGS. 32–37.—*Plectrocnemia potchina* sp. n. ♂. 32. wings; 33. genitalia lateral; 34. lower penis-cover (?) lateral; 35. genitalia dorsal, inferior appendages not shewn; 36. inferior appendages and 9th sternite; 37. lower penis-cover (?) ventral.

Genitalia ♂.—Apical margin of the 9th tergite produced at its centre and truncate, bearing four or five long hairs towards each angle; dorsal plate with the lower lateral margins much produced and strongly chitinized to form fairly long, upcurving processes with dilated apices; between them, the plate is membranous with apical margin slightly excised; a large, wide wart, almost amounting to a process, towards the base of the plate, fringed and directed outwardly; penis, from above, with a slender stem and dilated, bifurcate apex, the fork caliper-shaped with the apices touching; from the side, the fork appears as a rounded plate overhanging a narrow shelf; inferior appendages two-jointed, terminal joint small, tapering and curving upwards; lateral margin of the 9th segment produced to make a very small sidepiece and sparsely fringed with stiff hairs.

Length of the anterior wing ♂ and ♀ 7 mm.

One example dated 27.iv.1938; an example already in the British Museum is labelled China only and is lacking an abdomen.

Polycentropidae.

Plectrocnemia potchina sp. n. figs. 32–37.

Insect of moderate size with brownish, irrorated wings.

Genitalia ♂.—Apical margin of the 9th tergite strongly produced and triangular; superior appendages broad, leaf-shaped; penis-sheaths long, fine, divergent at the apices where they are separated from each other by the width of the segment; between them lies the membranous penis; on each side are three very stout, upcurving prongs arising from a common base, one behind the other, perhaps forming part of a lower penis-cover; inferior appendages broad and branched; outer branch broader than the inner, from the side; a small process armed with a few bristles at its apex arising from the upper margin of the outer branch on its inner surface and a sinuous process arising also from the inner surface, towards the centre.

Length of the anterior wing ♂ 6 mm., ♀ 8 mm.

Psychomyidae.

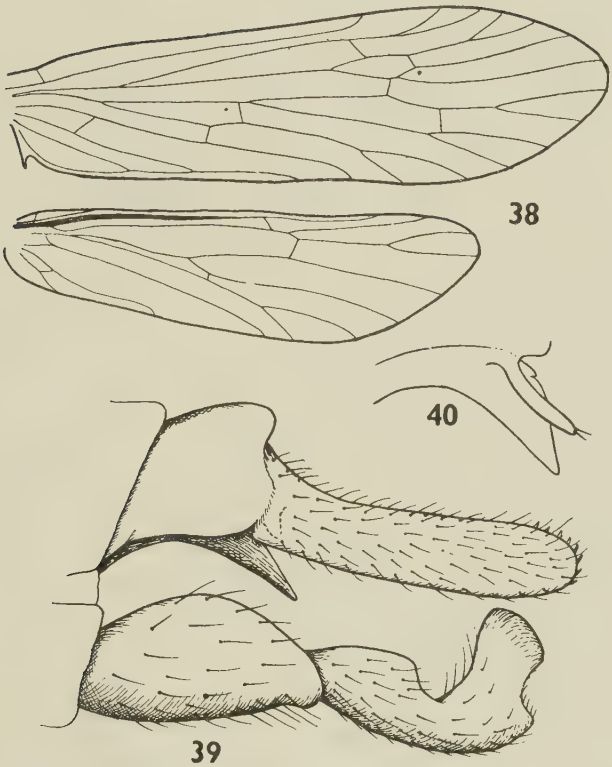
Ecnomus foochowensis sp. n. figs. 38–42.

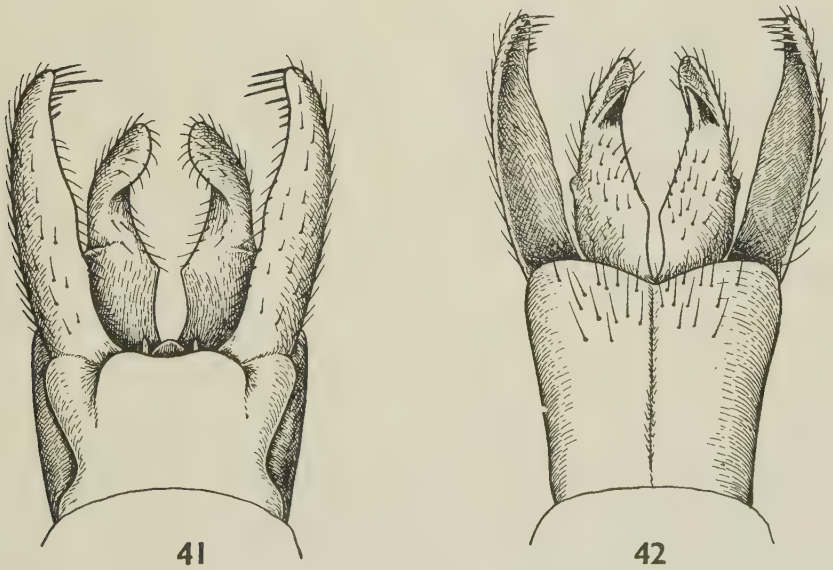
General appearance as in the European species *Ecnomus tenellus* Ramb. Spurs 3, 4, 4.

Genitalia ♂.—Apical margin of the 9th tergite slightly excised; superior appendages very long, with fairly closely fringed inner margins and short teeth at the apices; from the side, they are of equal thickness throughout their length; there is a minute branch tipped with a few hairs arising from the inner surface towards the base; upper penis-cover in the form of a pair of short, straight spines, each tipped with one or two bristles; penis short, its apex appearing from the side as a triangular shelf directed downwards; there is an obscure structure, only visible in the cleared preparation, which may be a lower penis-cover; it lies mainly within the 9th sternite, extending beyond the base of the inferior appendage; inferior appendages large, boot-shaped, heels directed distally, toes stout and directed upwards; 9th sternite strongly produced, with a central, longitudinal, impressed line.

Length of the anterior wing ♂ and ♀ 4 mm.

E. foochowensis, when pinned and dry, very closely resembles the European species *tenellus* Rambur.



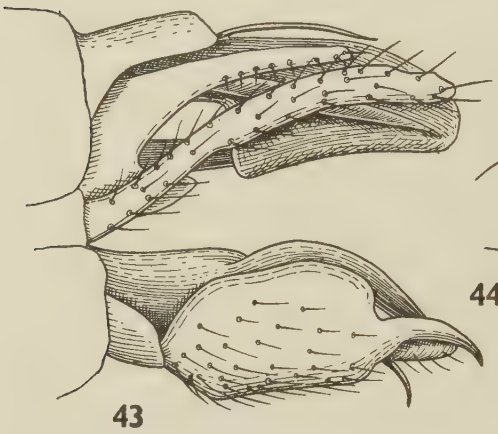


FIGS. 38–42.—*Ecnomus foochowensis* sp. n. ♂. 38. wings; 39. genitalia lateral; 40. penis and upper penis-cover lateral; 41. genitalia dorsal; 42. ventral.

Tinodes chinchina sp. n. figs. 43–46.

Insect very small and yellowish.

Genitalia ♂.—Dorsal plate short, nearly square, with the apical margin excised; beneath it, attached to the upper penis-cover, is a long, slender, transparent spine; superior appendages long and rather stout, completely denuded of fringe on the upper surface in the example under description; penis and upper penis-cover obscure, as long as the superior appendages, wide from the side, with the upper margin curving over slightly to make a broad beak; a pair of fine, spine-like penis sheaths; inferior appendages branched; there



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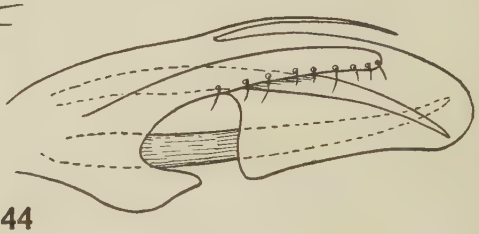

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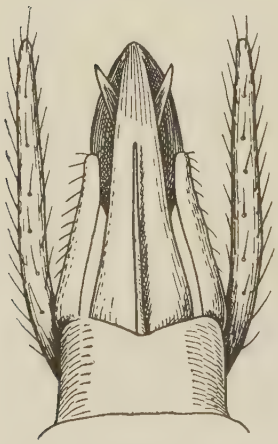

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FIGS. 43–46.—*Tinodes chinchina* sp. n. ♂. 43. genitalia lateral; 44. penis, upper penis-cover etc., lateral; 45. genitalia dorsal; 46. ventral.

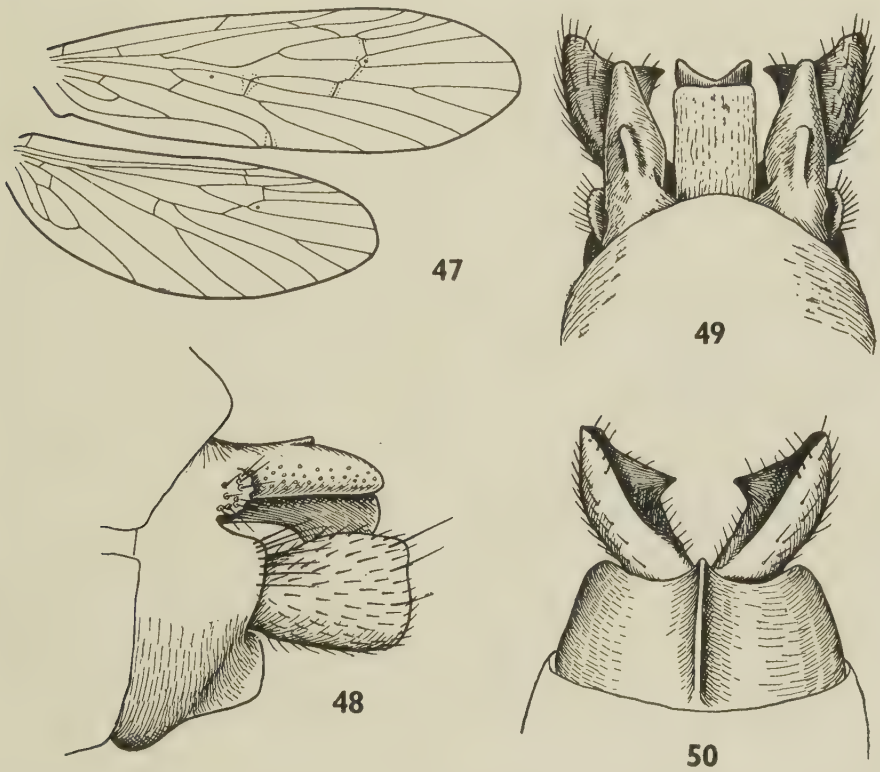
is a very broad base from which the outer branch, a stout, curved spine, arises at the apex; the second and inner branch is slightly shorter than the outer and broad, with an obtuse apex; the third forms a short, very fine, curved spine, arching downward from the base of the second; the fourth arises from the inner margin of the appendage, below the other three as seen from beneath; inside the bases of the inferior appendages, and uniting them, is a single process, broad at the base with an acute, produced apex, curving downward, as seen from the side.

Length of the anterior wing ♂ and ♀ 3 mm.

PHILOPOTAMIDÆ.

Chimarrha cachina sp. n. figs. 47–50.

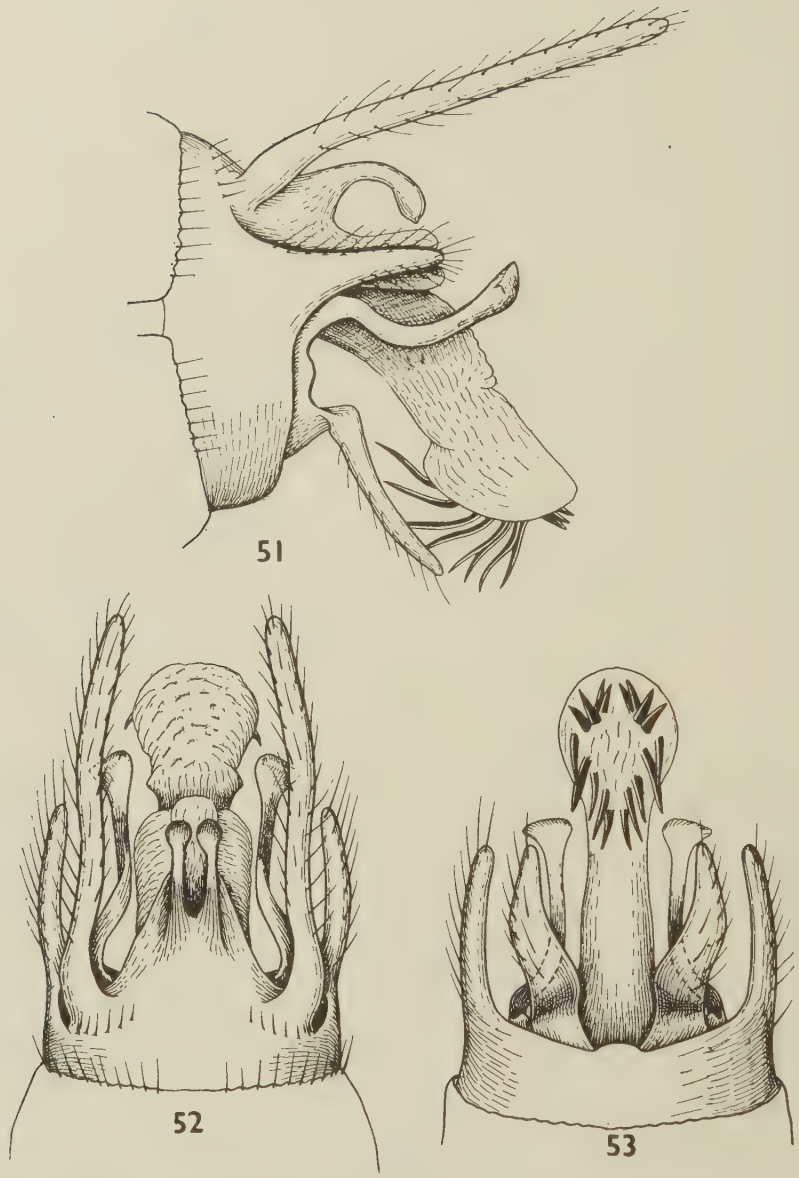
Insect black. In both wings, fork No. 1 is sessile and very narrow; in the anterior, on the denuded membrane, are three conspicuous, white marks, one at the base of fork No. 2 extending upwards along the cross-vein closing the discoidal cell and downwards along the cross-vein of the median cell; another at the basal angle of the median cell and a third at the arculus; in the posterior wing, fork No. 2 extends a little way beneath the discoidal cell.



FIGS. 47–50.—*Chimarrha cachina* sp. n. ♂. 47. wings; 48. genitalia lateral; 49. dorsal; 50. ventral.

Genitalia ♂.—9th tergite membranous; superior appendages fairly long, tapering and with a small ridge along the centre of the upper surface from near the base to about half-way, rather wide from the side, with a hairy wart on the outer margin at the base; penis straight, with a pair of internal, black spines; lower penis-cover nearly the same width as the penis, slightly longer, apex excised; inferior appendages short, with broadly truncate apical margins; viewed from behind, they are very thick with the distal surface slightly concave; the upper, inner angles are produced to form black spurs; there is a pronounced keel to the 9th sternite; no ventral processes.

Length of the anterior wing ♂ 5 mm., ♀ 6 mm.



FIGS. 51–53.—*Stenopsyche banksi* sp. n. ♂. 51. genitalia lateral; 52, dorsal, lower branches of inferior appendages not shewn; 53. 9th sternite, inferior appendages and penis.

Stenopsyche banksi sp. n. figs. 51–53.

General appearance dark brown with the usual dark and yellowish patches on the anterior wings.

Genitalia ♂.—Apical margin of the 8th segment thickened and set with a row of hairs; superior appendages long and slender; dorsal plate with the apical margin excised; at the base arises a pair of short processes set close together side by side and arching downward; sidepieces of the 9th segment produced and slender, extending nearly as far as the

apices of the upper branches of the inferior appendages; upper penis-cover membranous with excised apical margin; penis much exserted in the type, long, armed throughout its length with short spines which are directed distally and are contained within a membranous sleeve; at the apex, the penis projects beyond this sleeve and turns down and under so that the spines are here free; inferior appendages two-branched, inner branches a little longer than the processes of the dorsal plate, elbowed slightly towards their bases, apices dilated to obliquely truncate apical margins with the outer angles produced in minute spurs; outer branches short and slender, bent abruptly downward from near their bases.

Length of the anterior wing ♂ and ♀ 20 mm.

There is an additional ♂ paratype in the Museum collection bearing the label " Formosa, A. E. Wileman ".

Rhyacophilidae.

Pseudagapetus chinensis sp. n. figs. 54–57.

Insect brownish; wings with dark, reddish-brown clothing, darker towards the fringes; neuration as is usual in the genus.

Genitalia ♂.—Apical margin of the 9th tergite deeply excised; in the excision there is a long, stout, hood-like plate, perhaps united to an upper penis-cover; the centre is membranous with the sides a little more chitinized, apex excised; the plate is deep from the side; on each side is a slender, superior appendage, apex not dilated and inclining slightly outward, fringed with long, widely spaced hairs which, from the side, are seen to be directed upwards; penis concealed in the hood of the dorsal plate or upper penis-cover; inferior appendages long and stout, bearing two blackened warts on the inner surfaces, that nearer the apex the smaller; a pointed process, fringed on its lower surface, to the 6th sternite.

Length of the anterior wings ♂ and ♀ 4 mm.

List of species in the Yang collection.

Limnophilidae.

Nothopsyche intermedia Martynov. *Proc. zool. Soc. Lond.* **1930** : 101, 1930 (Shensi Province). 3 ♂♂.

* *Apatidelia martynovi* sp. n. 1 ♂.

Sericostomatidae.

Crunoeciella flava Ulmer. *Arch. Naturg.* **91** A. 5 : 83–86, figs. 75–79, 1926 (Kuangtung). 13 ♂, 6 ♀, one dated 17.iv.1936. In Ulmer's description of the species, it is stated that there are no scales on the anterior wings. In every male example in this collection, scales are present but they are only lightly attached and it may be that, in the type, they had become detached. The examples in this collection agree exactly with the figures of the type both in neuration and genitalia.

Goëra fissa Ulmer. *Arch. Naturg.* **91** A. 5 : 76, figs. 63–65, 1926 (Kuangtung). 1 ♂.

Molannidae.

Molanneria falcata Ulmer. *Deutsch. ent. Z.* **1908** : 347, figs. 8–12, 1908 (Japan). 2 ♂, 3 ♀.

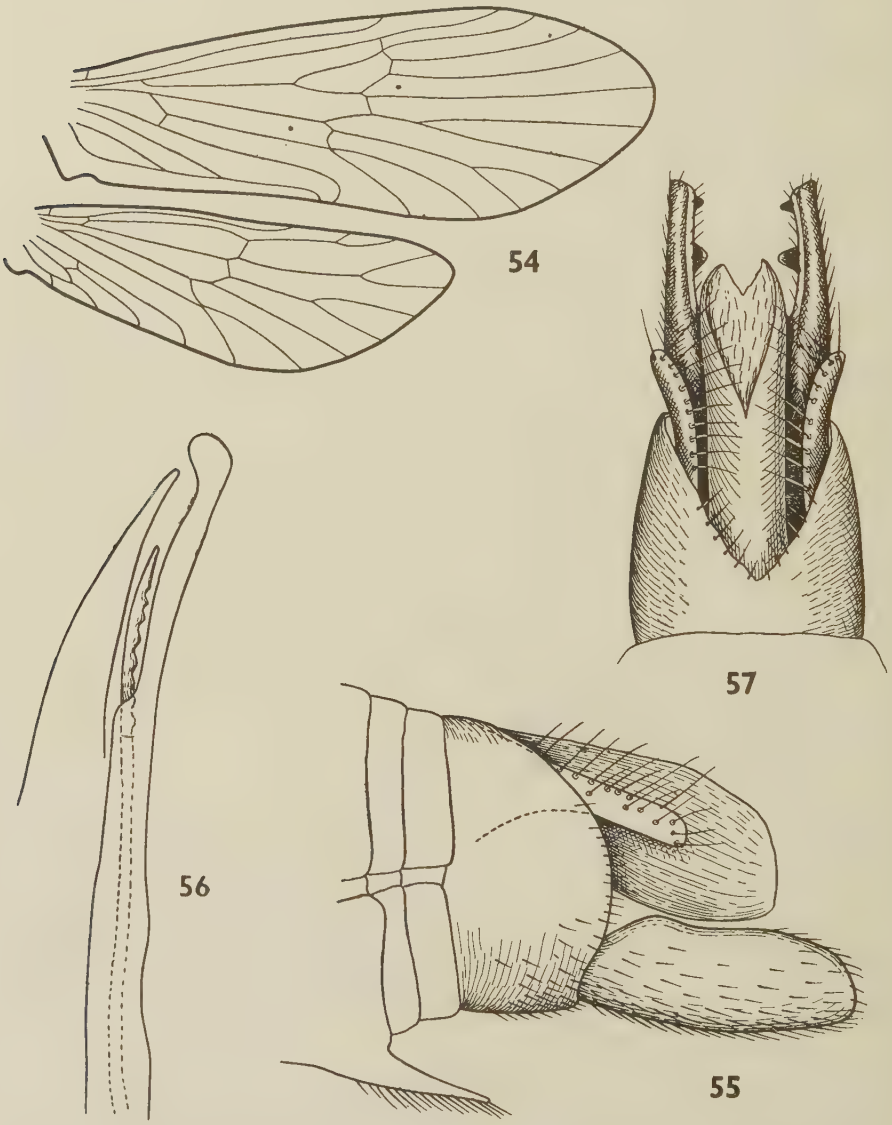
ODONTOCERIDAE.

Psilotreta kwantungensis Ulmer. *Arch. Naturg.* **91** A. 5 : 66–68, figs. 49–52, 1926 (Kuangtung). 1 ♂.

* *Psilotreta ochina* sp. n. 1 ♂, 1 ♀.

CALAMOCERATIDAE.

Ascalaphomerus finitimus McLachlan. *Trans. ent. Soc. Lond.* (3) **1** : 304, 1862 (N. China). 1 ♀.



FIGS. 54–57.—*Pseudagapetus chinensis* sp. n. ♂. 54. wings; 55. genitalia lateral; 56. penis, upper penis-cover and sheaths lateral; 57. genitalia dorsal.

Leptoceridae.

Triplectides magna Walker. *Cat. Neur. Brit. Mus.* : 73, 1852 (Van Dieman's Land). 2 ♂, 3 ♀.

* *Leptocerus inchinus* sp. n. 106 examples of both sexes.

* *Leptocerus yangi* sp. n. 2 ♂, 4 ♀.

* *Leptocerus fooensis* sp. n. 2 ♂, 5 ♀. One example dated 8.iv.1936.

Leptocerus sinensis Forsslund. *Ark. f. Zool.* **27** (A) (31) : 8–9, fig. 8, 1935. 2 ♂.

* *Oecetis orientalis* Martynov. *Trav. Inst. Zool. Acad. Sci. URSS.* **2** : 248–249, fig. 46, 1935 (Amur region). 36 examples of both sexes. One dated 6.vi.1936.

Hydropsychidae.

* *Polymorphanisus ocularis* Ulmer. *Notes Leyd. Mus.* **28** : 60, fig. 65, 1906 (Java). 1 ♀.

* *Amphipsyche proluta* McLachlan. *Ann. Soc. ent. Belg.* **15** : 70, pl. 2, fig. 7, 1872 (Amur region). 1 ♂. Dated 30.iv.1938.

Aethaloptera rossica Martynov. *Annu. Mus. zool. St. Petersb.* **15** : 385, figs. 27–30, 1910 (Amur region). 1 ♂, 1 ♀.

Macronema fastosum Walker. *Cat. Neur. Brit. Mus.* : 76, 1852 (Hong Kong). 34 examples of both sexes.

Macronema hospitum McLachlan. *Trans. ent. Soc. Lond.* (3) **1** : 307, 1862 (N. China). 2 ♂, 1 ♀.

Macronema lautum McLachlan. *Trans. ent. Soc. Lond.* (3) **1** : 308, 1862 (Hong Kong). 2 ♀. The examples in Mr. Yang's collection are rather smaller than the type series, and the markings are not exactly similar. It may be that a distinct species is involved.

* *Hydropsyche simulata* sp. n. 1 ♂, 7 ♀.

* *Cheumatopsyche banksi* sp. n. 7 ♂, 9 ♀.

* *Cheumatopsyche dubitans* sp. n. 1 ♂, 5 ♀. One dated 27.iv.1938.

Cheumatopsyche chinensis Ulmer. *Deuts. ent. Z.* **1915** : 47–48, figs. 14–15, 1915 (Pekin). 2 ♂, 1 ♀.

Diplectrona melli Ulmer. *Pekin nat. Hist. Bull.* **7** : 48–49, figs. 15–16, 1932–33 (Yunnan). 3 ♀. In the absence of a ♂, this determination must be considered a little doubtful.

Polycentropidae.

Dipseudopsis stellata McLachlan. *Tijdschr. Ent.* **18** : 16, pl. 2, fig. 11, 1875 (Shanghai). 1 ♂.

Hyalopsyche pilosa Navás. *Ent. Mag. Japan* **11** : 91, fig. 5, 1916 (China). 349 examples, mostly female.

* *Pseudoneureclipsis* sp. 1 ♀. Species not determined.

* *Plectrocnemia potchina* sp. n. 1 ♂, 2 ♀. One example dated 17.iv.1936.

Psychomyidae.

* *Ecnomus foochowensis* sp. n. 60 examples of both sexes.

* *Tinodes chinchina* sp. n. 2 ♂, 1 ♀.

Philopotamidae.

* *Chimarrha cachina* sp. n. 1 ♂, 1 ♀.

Stenopsyche griseipennis McLachlan. *Trans. ent. Soc. Lond.* (3) **5 :** 265, pl. 17, fig. 5, pl. 19, figs. 17–18, 1866 (E. India). 1 ♂, 7 ♀.

Stenopsyche angustata Martynov. *Proc. zool. Soc. Lond.* **1930 :** 74, figs. 15–16, 1930 (W. China). 1 ♂, 5 ♀.

* *Stenopsyche banksi* sp. n. 1 ♂.

Rhyacophilidae.

Rhyacophila sp. Undeterminable, abdomen wanting.

* *Rhyacophila anatina* Morton. *Trans. ent. Soc. Lond.* **1900 :** 6, pl. 1, figs. 17–18, 1900 (India). 1 ♂. There is a slight difference in the shape of the lateral lobes of the dorsal plate and also in the shape of the terminal joint of the inferior appendage, from the figures of the type. I consider these differences scarcely sufficient to indicate a distinct species.

* *Pseudagapetus chinensis* sp. n. 1 ♂, 1 ♀.

* New to the Chinese fauna.

ON THE DEVELOPMENT AND HOMOLOGIES OF THE GENITALIA AND THEIR DUCTS IN HYMENOPTERA

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Manuscript received 27th September, 1940.

Read 1st April, 1942.

With Twenty-five Text-figures.

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Introduction.

While in recent years the development and homologies of the genitalia and the efferent genital ducts in various insects have attracted the attention of a number of investigators, the order Hymenoptera has not been given the study its morphological interest merits. Earlier authors, Eaton (1866, 1868), Ganin (1869) and others, demonstrated the primary buds of the genitalia alone. The researches of Kraepelin (1873), Dewitz (1875, 1877), Seurat (1899), Michaelis (1900) and Zander (1900, 1903), had thrown much light on the subject and the order Hymenoptera was at that time among the best known. Zander in 1916 added a useful contribution to the literature. In recent years Tiegs (1922), Boulangé (1924) and George (1934, 1935) are the only authors who have gone into the development of the subject. With regard to the female genitalia, the exact situation and nature of the primary buds of these organs have been a matter of considerable difficulty. The correct interpretation of the origin and nature of the oviducts, the origin and evolution of the accessory genital organs, such as the spermatheca and accessory glands and the relation of these structures to the genitalia is still a matter of dispute. This study attempts to remove the discrepancies in the literature mentioned above.

The research was undertaken at the suggestion of Dr. A. D. Imms, F.R.S., whom I cannot sufficiently thank for his guidance and encouragement throughout the investigation. I am indebted also to Dr. W. H. Thorpe for his kind advice, and the award of a Government of India Scholarship is gratefully acknowledged.

Material and Technique.

All the material for this work was secured from the Cambridge district. The dissections were carried out with the aid of a binocular microscope and then stained with borax carmine. The fixatives employed were picro-chlor-acetic acid, aqueous Bouin's fluid and Petrunkewitsch fluid, and the material was embedded in paraffin wax of m.p. 52–56° C. It was necessary in the case of the bee and wasp larvae to dissect out most of the fat body in order to obtain a complete permeation with the fixatives, etc. Air bubbles were removed by means of a vacuum pump. Sections were stained either in Heidenhain's iron-haematoxylin and counter-stained in orange G, or with Delafield's haematoxylin and counter-stained in eosin, or both. Cuticular preparations were first treated with 5% KOH solution and then stained in carbol-fuchsin and borax carmine. The illustrations were made with the assistance of a camera lucida.

PART I.—THE FEMALE

Female Organs.

Nematus ribesii.

Adult organs.

The two ovaries fill the greater part of the body cavity; each is composed of several ovarioles firmly attached at their apices by their terminal filaments. The oviducts run posteriorly and ventrally, and in the region of the seventh segment open into a short oviduct. The spermatheca is conical and has a narrow duct which opens into the common oviduct. The counterpart of the associated tubular glandular parts (or receptacular glands) are absent in this

species. Posterior to the opening of the spermatheca the common oviduct continues as the vagina which opens by a wide mouth externally and in front of the anterior valves of the ovipositor. The accessory gland consists of a pair of branched organs which open by a short duct into a non-muscular vesicular part; from the latter a short duct opens at the base of the inner valves of the ovipositor.

Development of genitalia.

In the first-instar larva the buds of the genitalia are absent, and it is not until the third instar that a pair of ectodermal thickenings (imaginal buds) are evident on the ventral surface of each of the eighth and ninth segments. Those of the eighth segment are more widely separated from each other than those of the following segment (fig. 1, A and B). At a later larval stage these grow in size and it is in the final-instar larva that they become surrounded by peri-

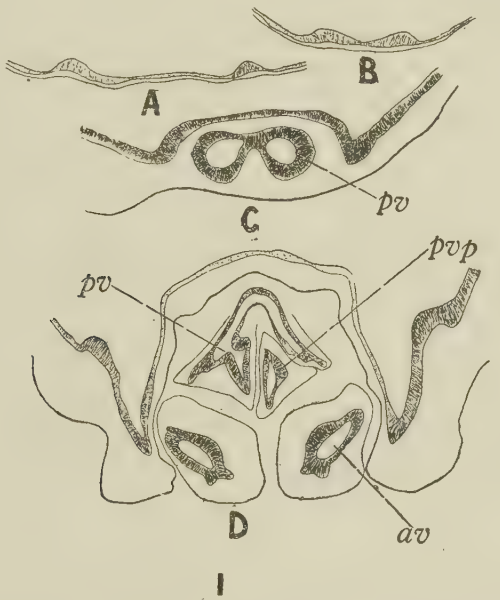

FIG. 1.—*Nematus*. A. T.S. passing through the 9th segment of a third-instar larva to show the buds on the 9th segment; B. the same of the 8th segment to show the buds of the ventral valves; C. T.S. of an early pupa to show the basal fusion of the posterior valves; D. the same to show the attachment of the posteriorly directed processes of the posterior valves.

podial cavities (*vide* Imms, 1938 : 201). In a larva which is about to spin its cocoon each bud of the ninth segment divides by a groove, which starts from the posterior border, into an inner and an outer pair. During the early prepupal stage the inner valves fuse along their basal dorsal margin (fig. 1, C). Each outer and inner valve of one side becomes separated more widely by the interception of the ninth sternum. This separation proceeds and the separating area after sclerotisation becomes the oblong plate. In the middle and late prepupal stages the fusion of the inner valves progresses posteriorly and the adult condition is attained in the early pupal stage. Each of the inner valves gives out ventrally from its anterior end a posteriorly directed process (fig. 1, D, *pvp*).

The pupal instar shows that these parts grow anteriorly, the saws as well as their supports diverge into arms, and the structures which have acquired an appendicular nature become sclerotised and take the position seen in the adult. The development of the genitalia was followed from the earliest larval instar up to the full-grown larva in *Cephus pygmaeus* and *Phymatocera aterrima* and these showed complete agreement with that of *Nematus*.

Efferent system.

The ovaries lie lateral to the gut in the fifth segment in the first-instar larva. The oviducts extend as fine thread-like solid cords and terminate in dilatations which rest on the ventral and lateral parts of the seventh segment (vide *Cephus*, fig. 2, A, *ta'*). During the later larval instars these ends grow and during the

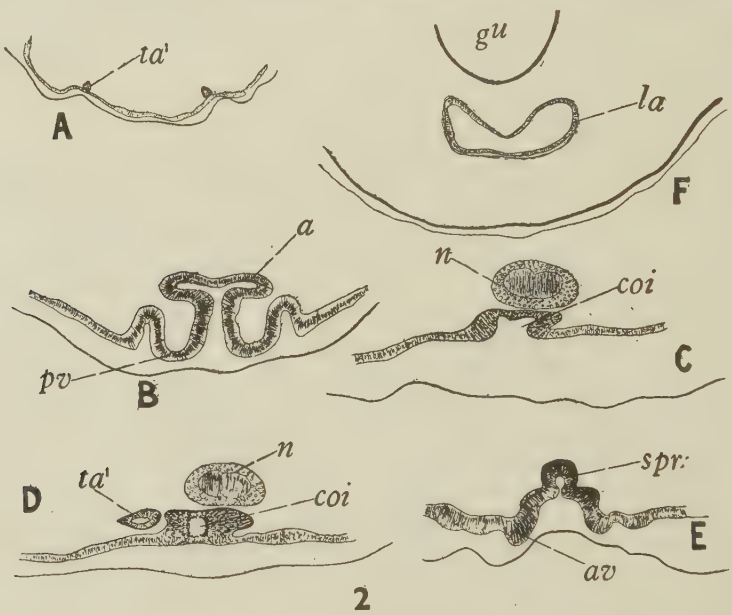

Fig. 2.—A. T.S. of a first-instar larva of *Cephus* to show the terminal ampullae of the oviducts; B–F. *Nematus*, B. T.S. of a late full-grown larva to show the development of the female accessory gland; C. and D. Serial T.S. of an early prepupa showing the development of the common oviduct; E. T.S. of a prepupa showing the development of the spermatheca; F. T.S. of an early pupa to show the anterior arms of the common oviduct.

final larval stadium they acquire a lumen. It is during a very late larval stage that the rudiment of the accessory gland arises from the bases of the inner valves as a median invagination, the upper flattened end of which gives out laterally a pair of arm-like projections (fig. 2, B, *ag'*) which are the rudiments of the associated glands. The anterior valves during this stage move towards the mid-ventral line and enclose a groove—that of the spermatheca.

In the early prepupa the arms of the rudimentary accessory gland begin to grow, the spermathecal groove deepens and the rudiment of the common oviduct arises as a median invagination. Its ventral lips meet anteriorly, from the hind margin of the seventh sternum (fig. 2, C, *coi*), and the terminal ampullae lie associated with this blind end (fig. 2, D, *ta'*).

The intervening wall between the rudiments of the spermatheca and of the common oviduct begins to shrink and the oviducts acquire a lumen.

In the middle prepupa the basal part of the accessory gland becomes globular; its apical end, by which it communicates with the accessory glands, narrows to form a short duct, and the anterior arms begin to branch. The spermathecal groove becomes conical (fig. 2, E, *spr*). The entire body wall between the rudiments of the spermatheca and the common oviduct is joined by a groove, the upper wall of which shrinks.

In the late prepupa the accessory gland increases in size. The rudiments of the common oviduct and of the spermatheca become contiguous by the further shrinking and deepening of their intervening wall. The common oviduct acquires a chitinous internal lining.

During the pupal instar the vesicle of the accessory gland enlarges considerably. The common oviduct and the vagina, which is the region posterior to the opening of the spermathecal duct, are lined by an outer muscular coat. Anteriorly the common oviduct becomes constricted into two lateral arms into which open the terminal ampullae of their respective sides (fig. 2, F, *la*). Further development in this instar results in the growth and differentiation of the organs which are already completed before the pupal instar is attained.

Observations were made on the efferent genital ducts of *Cephus* and *Phymatocera*, from the earliest larval instar up to the full-grown larva. They are in essential agreement with those made on *Nematus*.

Polemon liparae.

Adult organs (fig. 3).

The internal reproductive organs of *P. liparae* consist of a pair of ovaries (*ov*) lying ventro-lateral to the gut in the fourth to sixth segments. Each ovary is composed of seven to ten ovarioles which adhere closely to one another *in situ*, and the ova fill up a considerable part of the abdominal cavity. The oviducts (*o*) are short and thick and unite to form a muscular common oviduct. The spermatheca (*sp*) is composed of an apical tubular part and a vesicular basal part from which a duct opens into the roof of the common oviduct. The continuation posterior to the opening of the spermatheca is the vagina (*v*), which opens to the exterior in front of the anterior valves. The acid gland (*pg*) is a greatly branched structure which fills a considerable portion of the posterior part of the abdominal cavity. The poison sac (*ps*) is cone-shaped and its short narrow duct opens at the base of the sheaths. Adults of the Braconid *Alysia manducator* Panzer were dissected and the acid gland in them also showed a similar structure, which has been observed also by Seurat (1899) in the Braconid *Doryctes gallicus*. The alkaline gland is a small club-shaped structure which lies hidden under the greatly branched acid gland and opens a little anterior to its opening. In fig. 3, therefore, the alkaline gland has not been sketched.

Development of genitalia.

Young larvae of less than 1 mm. and 1·2 mm. length were examined. In these the buds of the genitalia were not discernible. They first appear in larvae 1·6 mm. long, and are clearly seen in larvae 2·4 mm. long. Those on the eighth segment are situated 0·03 mm. apart, while those on the ninth segment are 0·02 mm. apart. A larva of 8 mm. shows them still better developed. The pair on the ninth segment in a full-grown larva divides into an inner and an outer pair by a longitudinal split, as in *Nemeritis* (*vide* fig. 5, A). In the pre-

pupal instar the inner pair on the ninth segment fuses, and subsequent development shows that the pair on the eighth sternum become the stylets or anterior valves of the ovipositor, the inner fused pair their sheaths, and the outer pair the palp-like lateral valves.

Efferent system.

Larvae less than 1 mm. long show the ovaries (*ov*) situated laterally to the gut in the seventh segment and the terminal filaments of one ovary are connected to those of the opposite side above the gut. The oviducts (*o*) are short

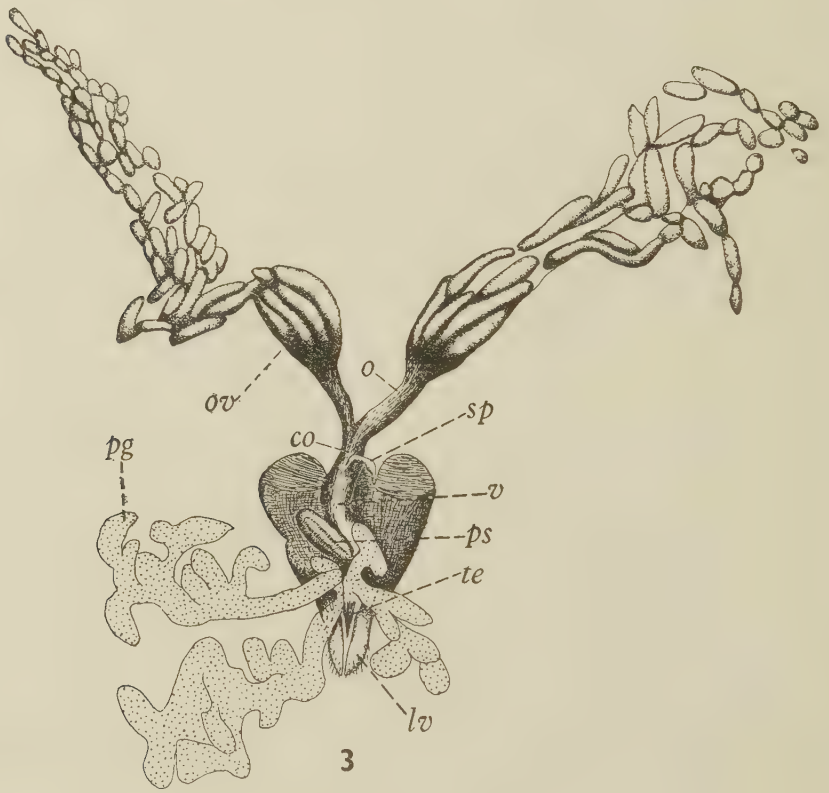

Fig. 3.—*Polemon liparae.* Adult organs, dorsal view.

and thin and bend downwards to terminate in ampullae (*ta'*) on the ventro-lateral surface of the seventh segment (fig. 4, A). The walls of the ampullae are composed of large cells and their inside appears to be hollow. Larvae of 1·2 mm. and 1·6 mm. showed more or less the same condition except that the ampullae had increased in size. A larva 2·4 mm. long showed localised thickening of the ectoderm on which the terminal ampullae were lodged. These thickenings are more widely separated than those of the following segment. The subsequent development up to the full-grown larva shows that the oviducts thicken in diameter and the buds on the seventh segment shift more towards the median plane. In a full-grown larva the rudiment of the acid gland arises as a median globular invagination from between the bases of the inner valves.

Apically this gives out four diverticulae—two from its anterior and two from its posterior end. These form the main rami of the future greatly branched gland. The vesicular part becomes the poison sac and the basal portion narrows to form the poison duct. The anterior valves move near each other in the mid-ventral line.

In the full-grown larva the rudiment of the alkaline gland arises as a median invagination a little anterior to that of the acid gland. At the bases of the anterior valves is a small invagination which is the rudimentary spermatheca. A fourth median invagination arises from the ectoderm lying between the

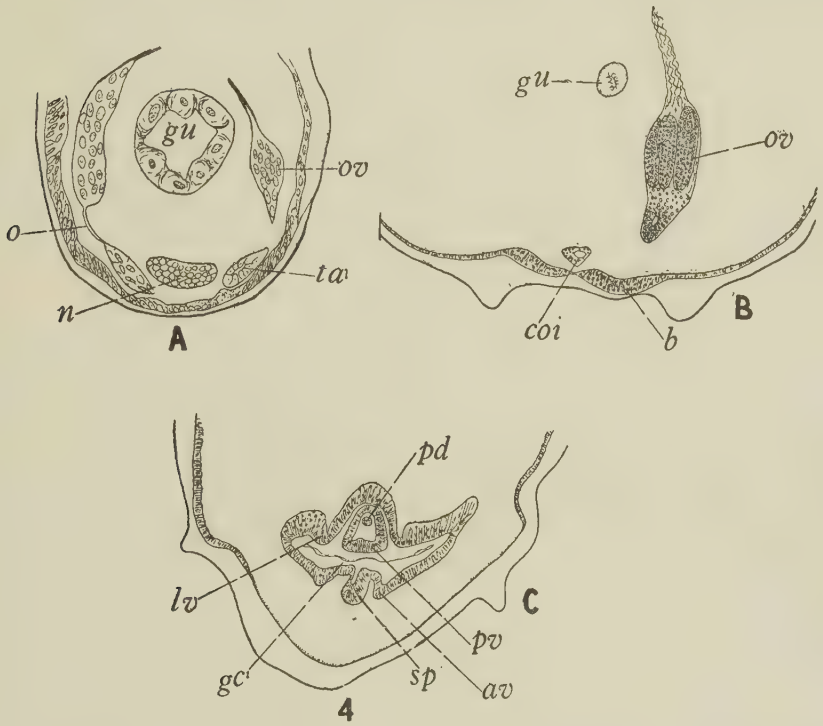

Fig. 4.—*Polemon*. A. T.S. of a larva less than 1 mm. long to show the disposition of the ovaries and their ducts; B. T.S. of a full-grown larva showing the rudiment of the common oviduct; C. T.S. of an early pupa to show the position of the ventral valves.

imaginal discs of the seventh segment and is the rudiment of the common oviduct (fig. 4, B, *coi*).

In the prepupa the entire region of ectoderm between the invagination of the common oviduct and that of the spermatheca becomes invaginated so that the two invaginations are carried deeply inwards. The intervening wall between these two invaginations begins to shrink. No trace of the imaginal buds of the seventh segment is evident. In a late prepupa and early pupa the appendages of the genitalia are also invaginated so that the articulations of the anterior valves of the ovipositor come to lie on the ventral wall of the genital chamber (fig. 4, C, *av*). The acid gland becomes greatly branched. The alkaline gland is better developed and the rudiment of the spermatheca becomes differentiated into an apical portion, which represents the gland, and a vesicular basal portion

or the spermatheca proper. The intervening wall between the common oviduct and the spermatheca shrinks further and the oviducts establish connection with the common oviduct. During subsequent development the openings of the common oviduct and the spermatheca become contiguous, as in *Nematus* or *Vespula*. A further deepening of the genital chamber and growth and differentiation of the other structures occur until the adult condition is reached.

Nemeritis canescens.

Adult organs.

The reproductive organs of *Nemeritis* have been described and figured by Krieger (1927). The ovaries, which lie in the fourth to sixth segments, are each composed of 10–12 ovarioles. The anterior end of each oviduct is dilated, while the posterior ends join into a common oviduct. The common oviduct dilates posteriorly into a vagina which opens posterior to the articulation of the stylets. The spermatheca is absent in the adult. There are two tubular acid glands which open by a duct into a bag-like poison sac. The poison sac, in its turn, opens by a narrow duct at the base of the posterior valves of the ovipositor. The alkaline gland is a tubular structure which opens a little anterior to the aperture of the acid gland.

Development of genitalia.

In the first-instar larva the rudiments of the genitalia are not discernible. They are present in the second-instar larva, on the ventral surface of each of the eighth and ninth segments as a pair of ectodermal thickenings. These imaginal buds lie close to each other. In the fourth and fifth instars the buds are as in the preceding instar except that they have grown considerably. During the fifth instar they become sunk in peripodial cavities. Those on the ninth segment divide by a longitudinal vertical division into an outer and an inner pair (*vide* fig. 5, A). The buds of the inner pair fuse at a late larval stage. The subsequent development proceeding during the prepupal and pupal instars involves the differentiation and growth of these three pairs. Those of the eighth segment become the stylets, the fused pair on the ninth become their sheath while the outer pair on the ninth become the palp-like lateral valves. The anterior diverging arms of the stylets and their sheath are the elongations of these structures occurring during the pupal instar.

Efferent system.

In the first-instar larva the ovaries lie dorso-lateral to the proctodaeum in the ninth segment. The oviducts are extremely fine cords and extend anteriorly from the ovaries but are soon lost in the mesenchyme and fat cells in the body cavity.

In the second instar the ectoderm on the ventral surface of the seventh segment, in the situation of the future imaginal discs, shows a slight thickening. The ovaries are still located in the ninth segment and their terminal filaments meet above the proctodaeum. The oviducts extend anteriorly in a ventral direction as far as the thickenings on the seventh sternum. There are no definite terminal ampullae present, the anterior ends of the oviducts being in connection with mesenchyme present on the thickenings of the ectoderm. In the third and fourth instars the loose cells of the mesenchyme, in which the oviducts terminate, take a more regular and rounded form. In the early fifth instar the terminal ampullae are clearly discernible and each has a distinct

lumen. The imaginal discs are better developed, but they are considerably smaller, and also more widely separated from each other, than those of the following segments. At a more advanced stage a median groove develops from the bases of the posterior valves. This is the rudiment of the acid gland (fig. 5, B, *pgr*). Simultaneously with the above groove a second median groove develops from the bases of the anterior valves and is the rudiment of the spermatheca, the imaginal discs of the seventh sternum being widely separated by a thin intervening ectoderm (fig. 5, C). At a still later stage the rudiment

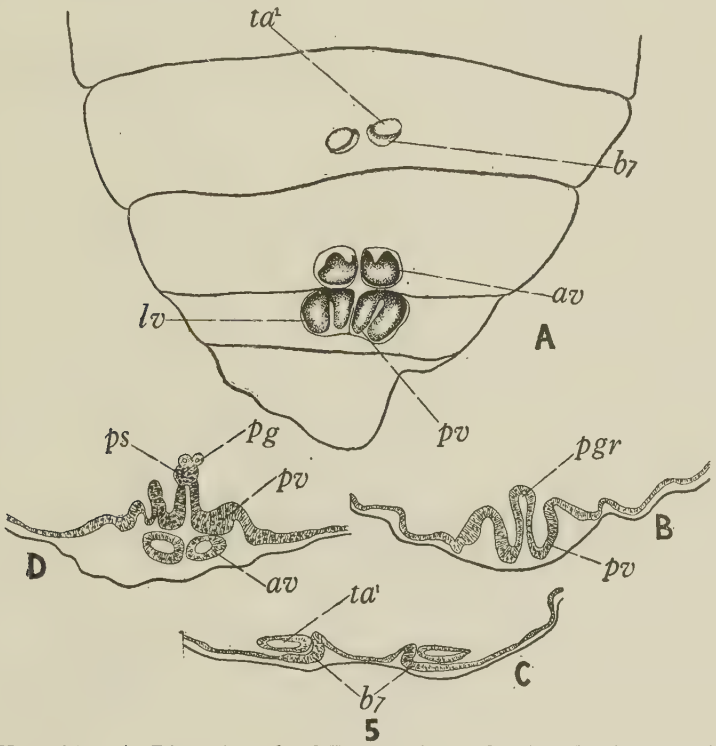

FIG. 5.—*Nemeritis*. A. Dissection of a full-grown larva showing the division of the pair of buds on the 9th segment (dorsal view); B. T.S. the same showing the development of the acid gland; C. the same showing the intervening ectodermal wall between the buds of the 7th sternum; D. the same showing the developing acid gland.

of the acid gland becomes differentiated into a vesicular part which gives out from its apical anterior end a pair of adjoining papillae. During subsequent development the basal portions of these papillae elongate to form the conducting channel and the papillae grow to form the acid glands, while the vesicular part forms the poison sac (fig. 5, D, *ps*). A little anterior to the opening of the acid gland another median invagination arises which is the rudiment of the alkaline gland (fig. 6, A, *al*). The rudiment of the spermatheca at this stage assumes a bag-like shape.

The common oviduct (*coi*) arises as a median invagination of the ectoderm between the imaginal discs of the seventh segment, the anterior end of which is depressed in the middle to form two short arms (fig. 6, B). The terminal ampullae move and come to lie in association with these arms of the rudi-

mentary common oviduct. The intervening wall between the invaginations of the spermatheca and the common oviduct begins to shrink. The ovipositor begins to move anteriorly so that the organs of the efferent system become anteriorly displaced.

In an early prepupa the lower lips of the invagination of the common oviduct meet and into its lateral arms the ampullae open. The imaginal discs,

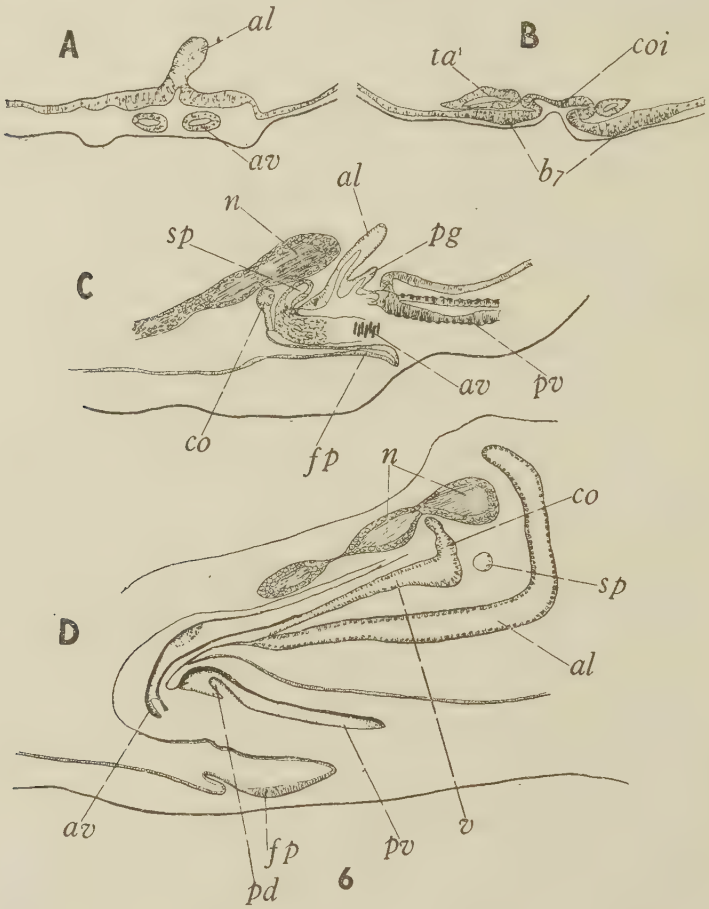

Fig. 6.—*Nemeritis.* A. T.S. of a late full-grown larva to show the developing alkaline gland; B. the same to show the median invagination of the common oviduct and its relation with the buds on the 7th sternum; C. L.S. of a prepupa showing the disposition of the internal reproductive organs. The gonopore lying anterior to the anterior valves; D. L.S. of a pupa showing the adult condition of the reproductive organs. The gonopore lying posterior to the anterior valves.

which in the previous stage were visible, are no longer distinguishable. The entire wall between the invagination of the spermatheca and that of the common oviduct becomes sunken and there is a further shrinking of the intervening wall so that in the later prepupal stage the two structures become contiguous (fig. 6, C).

The female gonopore still lies posterior to the stylets in the early pupa. It

is in the later pupal stage that there is a rapid forward shifting of the ovipositor so that the anterior attachments of the stylets migrate past the opening of the spermatheca and that of the common oviduct, *i.e.*, the female orifice becomes displaced behind the anterior valves (fig. 6, D). Furthermore, it is during this period that the ovaries change their posterior position and become placed anteriorly as they are found in the imago. There is a further deepening of the genital cavity, and the spermatheca, which is absent in the adult, persists in a rudimentary condition even in the very late pupa.

Pteromalus liparae.

Adult organs (fig. 7).

The internal reproductive organs of *P. liparae* consist of the ovaries (*ov*) which lie dorso-lateral to the gut in the fifth to sixth segments. Each ovary is

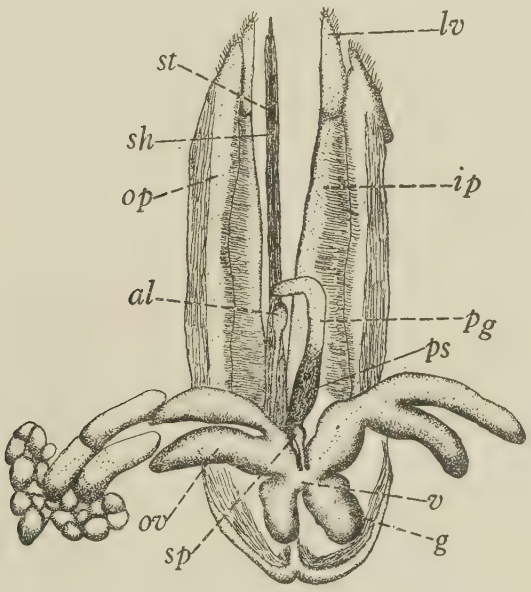

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FIG. 7.—Adult organs of *Pteromalus liparae* (dorsal view).

composed of two ovarioles. The oviducts are short and join in a short common oviduct which dilates into the vagina (*v*). The vagina opens posterior to the stylets, and a pair of globular sac-like pouches (*g*), one on either side of it, open into the former. James (1926) found in *Harmolita* (*Isosoma*) two pairs of similar pouches which he designated the primary and secondary accessory glands. Grandi (1929) in *Blastophaga psenes* found only one pair of such structures which he designated "ghiandole accessorie." The spermatheca (*sp*) consists of the three usual parts, an apical glandular part, the sac-like portion or spermatheca proper, and a sperm duct which opens into the roof of the anterior median part of the common oviduct at its junction with the vagina. The acid gland (*pg*) consists of an apical glandular part and a basal sac-like portion (*ps*) (corresponding to the poison sac) from which a duct opens at the base of the posterior valves. It may be pointed out here that James (1926), who

worked on *Harmolita*, stated that the acid gland degenerates in the adult. In *P. liparae* no such degeneration was observed. The alkaline gland (*al*) opens a little anterior to the opening of the acid gland. It is a tubular structure of about half the size of the acid gland with a thickened apical end.

Development of genitalia.

No trace of the imaginal discs of the genitalia is evident in larvae less than 1 mm. long. A larva 1·4 mm. in length showed on the ventral surface of each

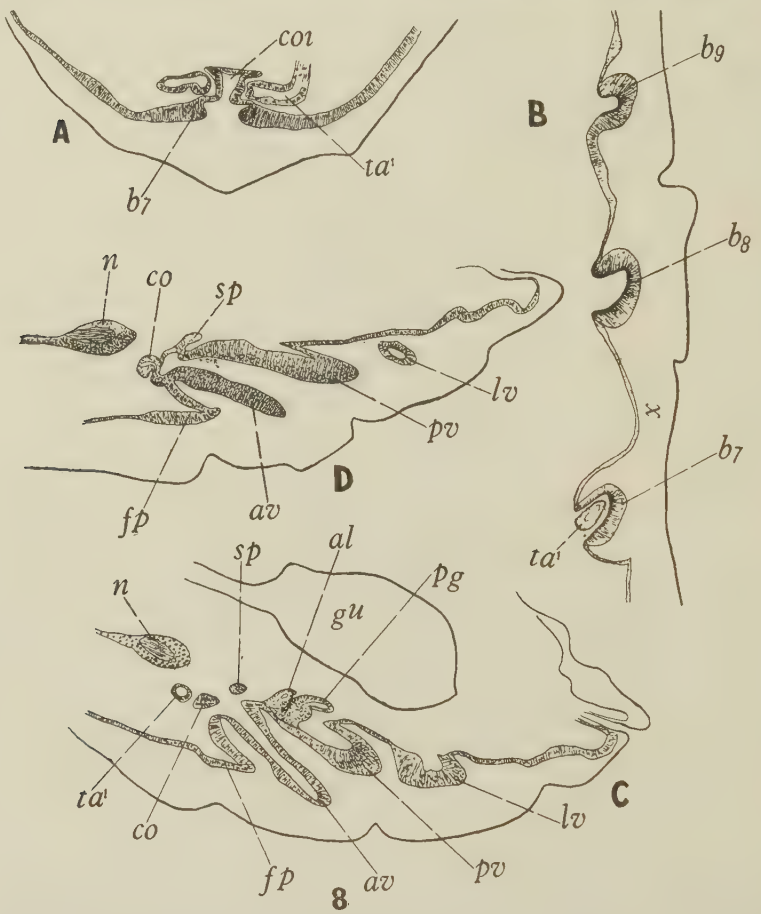

Fig. 8.—*Pteromalus*. A. T.S. of a full-grown larva showing the developing common oviduct; B. L.S. of the same showing the disposition of the buds on the 7th to 9th sterna; C. and D. Serial L.S. of a late full-grown larva showing the process of approximation of the common oviducal and spermathecal rudiments.

of the eighth and ninth segments a pair of minute ectodermal thickenings. Those of the eighth are as widely separated as those of the following segment. In a larva of 2·4 mm. in length these imaginal discs enlarge but there are no peripodial cavities formed till the larva is full grown. At a late stage in a full-grown larva the buds on the ninth segment become differentiated into an inner and an outer pair. Subsequent development shows that those on the eighth

segment become the stylets, the inner pair on the ninth fuse and become their sheath and the outer pair on the ninth become the palp-like lateral valves.

Efferent system.

The gonads lie dorso-lateral to the gut in the region of the seventh to eighth segments in larvae less than 1 mm. long. They are oval in shape and the sexes can be distinguished by the direction in which the gonoducts point. In the male the vasa deferentia proceed in a posterior direction towards the ventral surface of the ninth segment and in the female the oviducts start in a posterior direction but dip down and curve back, thus becoming directed forwards towards the ventral surface of the seventh segment. The oviducts are without

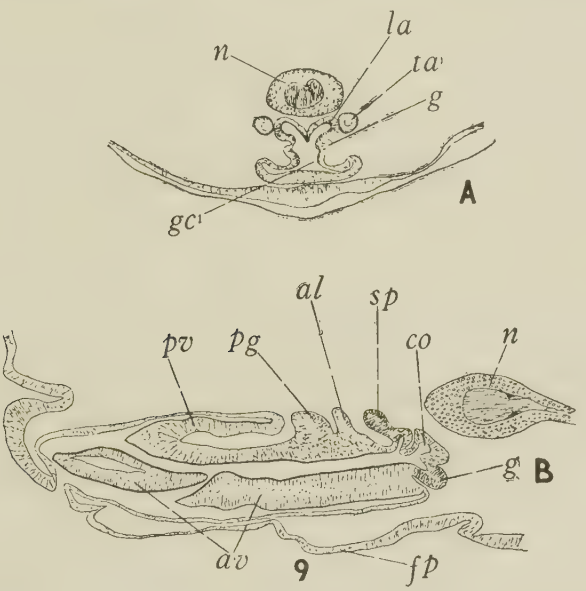

Fig. 9.—*Pteromalus.* A. T.S. of first-day pupa showing the lateral arms (*la*) of the common oviduct; B. L.S. of a prepupa showing the condition of the female organs as seen in the adult. The female orifice lying posterior to the ventral valves.

a lumen and I was unable to trace them right up to their termination at this early stage of development. The next stage larva, of 1·4 mm. length, however, showed the terminal ampullae situated on the median and lateral parts of the ventral surface of the seventh segment. A larva 2·4 mm. in length showed the ectoderm beneath the terminal ampullae thickened, and these buds are more widely separated than those of the following segment. Each ampulla is made up of a single layer of elongated cells enclosing a small space.

In the full-grown larva the imaginal discs enlarge and protrude and become surrounded by peripodial cavities while the ampullae acquire a distinct lumen. The rudiment of the acid gland appears as a median groove from the bases of the posterior valves; the spermatheca arises as a similar groove from the bases of the anterior valves; and from the region between the imaginal discs on the seventh segment, a median invagination arises which is the rudiment of the common oviduct (fig. 8, A, *coi*). The imaginal discs of the seventh segment are present below this groove and quite separate from it (*b7*). At a later stage

the alkaline gland also appears as a median invagination a little anterior to the invagination of the acid gland. The intervening wall of ectoderm (*x* in fig. 8, B) shrinks and becomes invaginated; the buds of the seventh segment protrude greatly and become merged with the subgenital plate, as may be seen from figs. 8, B and C; and the rudimentary common oviduct moves anteriorly and establishes connection with the rudiment of the spermatheca (fig. 8, D).

In the prepupal instar the rudiment of the acid gland becomes differentiated into an apical glandular part and a basal vesicular part, and the spermatheca also shows a similar differentiation. From the basal anterior part of the common oviduct arise a pair of pouches, the future accessory glands (fig. 9, A and B, *g*). A median constriction which starts from the dorsal surface divides the anterior end of the common oviduct into two short ducts with blind anterior ends (*la*), on which rest the respective terminal ampullae (fig. 9, A). This condition is seen even in the one-day-old pupa. The openings of the spermatheca and that of the common oviduct are displaced further posteriorly owing to the forward shifting of the ovipositor (fig. 9, B). During the early, middle and late pupal stages the organs of the imago already formed grow and undergo histological differentiation, and it is during the later pupal period that the ampullae open into their respective lateral arms of the common oviduct.

Vespula germanica.

Adult organs.

The reproductive organs of the worker are in general similar to those of the queen except that the ovaries and the spermatheca are reduced and the ovarioles filamentous.

The internal reproductive organs consist of a pair of ovaries which are situated lateral to the gut in the fourth to sixth segments. Each ovary is composed of four to six attenuated ovarioles the terminal filaments of which unite with the corresponding structures of the ovary above the gut on the opposite side. From each ovary an oviduct passes back and, in the region of the posterior margin of the sixth segment, dips sharply and joins the other to form a common oviduct which opens into the genital chamber. The spermatheca consists of a globular vesicular sac or spermatheca proper, and a pair of tubular glands and a narrow duct which connects the globular sac with the roof of the common oviduct at its junction with the genital chamber. There is a pair of coiled tubular acid glands opening separately into a conspicuous muscular poison sac which is connected by a narrow duct with the base of the stylet-sheath. The alkaline gland is smaller and its opening is situated a little anterior to that of the poison duct.

Development of the genitalia.

The development of the genitalia agrees closely with that of *Nemeritis* except that when the imaginal discs are discernible the pair on the eighth segment are more distantly situated from each other than those on the hinder segment. I have studied the development of the triangular and the oblong plates and conclude that the former structures represent the remnants of the eighth sternum, and the latter those of the ninth.

Efferent system.

The ovaries in a larva about 2 mm. long lie dorso-lateral to the gut in the region of the fourth and fifth segments. From each ovary extends postero-

laterally a thread-like oviduct without a lumen. In the region of the seventh sternum they dip low and end in hollow terminal ampullae the walls of which are composed of loose cells. These ampullae rest on the imaginal discs of the seventh sternum which are more widely separated from each other than those of the following segments, and are not surrounded by peripodial cavities. Subsequent development, leading to the full-grown larva, shows enlargement of the ampullae and a spreading of the cells that constitute it.

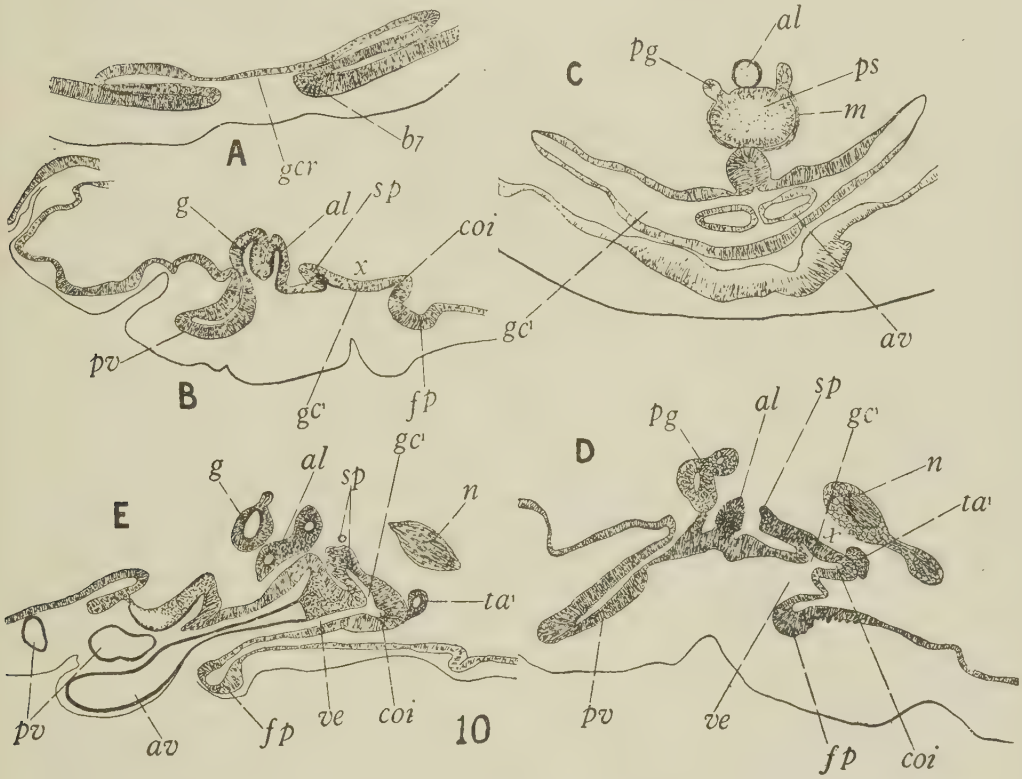

FIG. 10.—*Vespula*. A. T.S. of a prepupa to show the depression of the genital chamber; B. L.S. of an early prepupa to show the invaginations of the acid gland, alkaline gland, spermatheca and the common oviduct; C. T.S. of a prepupa showing the developing acid gland; D. the same showing the shrinking of the ectoderm (*x*) between the invaginations of the common oviduct and that of the spermatheca and the formation of the vestibulum; E. L.S. of a late prepupa showing the approximation of the spermatheca and the common oviduct.

In the full-grown larva the rudiment of the acid gland is a median invagination which arises between the bases of the inner valves. The discs of the eighth segment move in the mid-ventral line.

In the early prepupa the invagination of the acid gland becomes differentiated into an apical glandular part and a basal vesicular part which is the rudiment of the poison sac. A deep depression originates anterior to the terminal ampullae and their associated imaginal discs. This is the rudimentary genital chamber (fig. 10, A, *gcr*). At a slightly later period the anterior lower lips of this depression meet to form the rudimentary common oviduct. The

ampullae move and come in connection with the common oviduct, and the entire ectodermal wall between the common oviduct and the rudiment of the spermatheca, which arises at this stage as a median invagination from the bases of the anterior valves, becomes sunken (fig. 10, B). The cells of the discs of the seventh segment become spread posteriorly and merge with the subgenital plate (fig. 10, B, *fp*).

In the middle period of the prepupa the oviducts acquire a lumen. A pair of papilla-like outgrowths arise from the anterior end of the globular poison sac (fig. 10, C, *pg*), which are the rudiments of the poison glands. Mesenchymatous cells cover the surface of the poison sac with a sheath which, in subsequent development, forms its thick muscular coat (*m*). A little anterior to the invagination of the acid gland arises another median invagination whose apical end curves above the poison sac and points backward. This is the rudiment of the alkaline gland (*al*). This structure also is covered with a sheath of mesenchymatous cells. The invagination of the spermatheca becomes differentiated into an apical vesicular part, from the apex of which arise a pair of papillae. As in the honey bee, the vesicular part forms the spermatheca proper and the papillae grow to form its associated tubular glands. The genital chamber deepens further and the ectodermal wall (*x*) intervening between the invaginations of the spermatheca and the rudimentary common oviduct shrinks so that the two structures are approximated more than in the previous stage (fig. 10, D).

In the late prepupa the rudiments of the spermatheca and of the common oviduct approximate at this stage by the further shrinking of their intervening wall (*x*), thus becoming contiguous (fig. 10, E).

At a late pupal stage the ampullae open into the common oviduct. There is no displacement of mesodermal oviducts by the ectoderm. Nor is there any formation of the lateral ducts from the anterior end of the common oviduct, as have been shown to be present in some forms previously described.

Prosopis krieschbaumeri.

Adult organs (fig. 11).

The internal reproductive organs of *Prosopis* consist of a pair of ovaries (*ov*), each of which is composed of three ovarioles situated in the fifth segment. The terminal filaments of one ovary are united above the gut with those from the ovary of the opposite side. The oviducts (*o*) join into a short common oviduct (*co*) in the region of the sixth sternum. The common oviduct posterior to the opening of the spermatheca (*sp*) continues as the vagina (*v*) which dilates behind and opens anteriorly to the anterior valves. The spermatheca is composed of three regions: (1) a pair of tubular glands which open into (2) a globular spermathecal sac or spermatheca proper from which (3) a narrow duct emerges and opens at the junction of the common oviduct and the vagina. Similarly the acid gland consists of three regions—a pair of short coiled tubular glands (*pg*) which join into a duct opening into a non-muscular poison sac, from which a duct leads to open at the base of the stylet-sheath. A little anterior to the opening of the acid gland the alkaline gland (*al*) opens. This is a comparatively large tubular structure.

Development of genitalia.

The development of the genitalia is similar to that of *Vespula*.

Efferent system.

The ovaries of a full-grown larva lie dorso-lateral to the gut in the fourth and fifth segments. The oviducts extending from them end in hollow terminal ampullae which rest on the corresponding imaginal discs on the seventh sternum. These discs of the seventh segment are more widely separated from each other than those of the following segment. At a later stage the cells that compose these discs spread and are not such prominent structures as in the previous stage.

In the prepupal instar the acid gland is a median invagination which arises

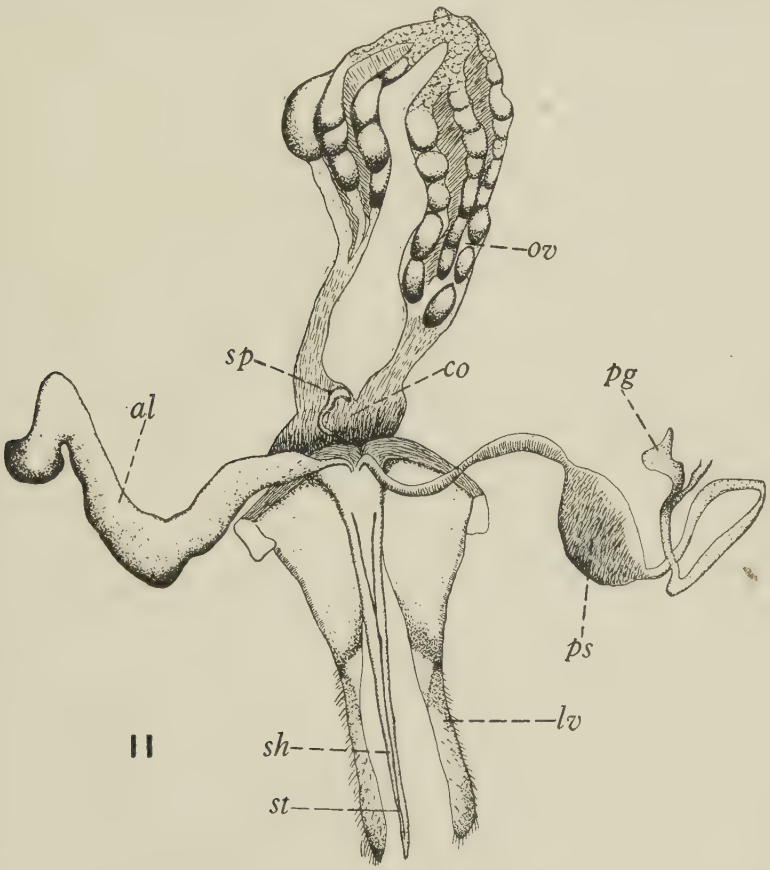

FIG. 11.—Adult organs of *Prosopis* (dorsal view).

between the bases of the posterior valves. A little anterior to this arises the rudiment of the alkaline gland, also as a median invagination, but this invagination is smaller than that of the acid gland. From the bases of the anterior valves arise the rudiment of the spermatheca as a median invagination with a globular upper part; from the apex of the latter arises a pair of papillae lying close to each other. The common oviduct arises as a median invagination from the posterior margin of the seventh sternum. The entire ectodermal wall, anterior to the rudiment of the spermatheca and posterior to that of the common oviduct, becomes depressed. This is the rudiment of the genital chamber.

The terminal ampullae (*ta'*) move to lie in association with the common oviduct. The discs cannot be traced as separate structures at this stage. At a later stage the intervening ectodermal wall, between the rudiments of the common oviduct and that of the spermatheca, shrinks still further, the genital chamber or vagina deepens and the oviducts acquire a lumen.

Young, medium and old pupae were examined. During these stages the globular part of the acid gland, which becomes the poison sac, enlarges, and from its apical end buds out a pair of papillae which are united basally. This basal portion grows into a tubular duct while the apical free portions form a pair of short coiled acid glands. The apical papillae of the spermatheca grow and form the spermathecal glands, while the basal sac enlarges to form the spermatheca proper. The alkaline gland undergoes a rapid growth, and by the deepening of the genital chamber and further shrinking of the ectodermal wall between the spermatheca and the common oviduct, the two structures become contiguous. Further development shows growth in these structures until they attain the condition seen in the adult.

Apis mellifica.

Adult organs.

The female reproductive organs of *Apis mellifica* have been described by Kraepelin (1873), Cheshire (1886), Zander (1916), Bishop (1920), Snodgrass (1925) and others. They resemble those of a *Vespula germanica* worker in all important respects, but the following differences are worth mentioning.

1. The ovaries suffer greater arrestation of development than in *Vespula*. Hence the ovarioles are not clearly differentiated and because of this the terminal filaments atrophy and the ovaries come to lie lateral to the gut, and not dorso-lateral as is the case in *Vespula*.

2. The poison sac is a non-muscular structure and the associated tubular glands join into a common duct which opens into the poison sac. In the case of the wasp the tubular glands open separately and directly into the muscular poison sac.

Development of genitalia.

In a young larva 2·5 mm. in length a pair of ectodermal thickenings lie on the ventral surface of each of the eighth and ninth segments. Those on the eighth segment are more widely separated from each other than those of the following segment. These imaginal discs are surrounded by pocket-like spaces, the " peripodial cavity." In the wasp these cavities do not appear until the larva is fully grown. In larvae 1 cm. long, there is an increase in the size of the discs and they commence to protrude outwards. In full-grown larvae a groove similar to that in the wasp divides each bud on the ninth segment into an inner and an outer pair. In the full-grown larva and early prepupa these three pairs of buds take an appendicular appearance. With subsequent development in the pupal stage the pair on the eighth segment becomes the stylets, the inner pair on the ninth forms their sheaths, and the outer pair on the same segment forms the palp-like lateral valves. I studied the development of the triangular and oblong plates and found that they represent the remnants of the eighth and ninth sterna. Further development leads to growth and sclerotisation of the parts.

Efferent system.

The ovaries of larvae about 2·5 mm. long lie dorso-lateral to the gut in the fifth abdominal segment. From each ovary an oviduct extends in a postero-lateral direction as a very delicate cord without a lumen. These cords terminate in hollow terminal ampullae. Each of the ampullae rests on an imaginal disc present on the seventh sternum. With development the discs and the ampullae grow larger. In full-grown larvae a median invagination, the rudiment of the acid gland, arises between the bases of the posterior valves. The anterior valves move in the median line. In the capped larva the invagination of the acid gland becomes differentiated into an apical tubular part and a globular

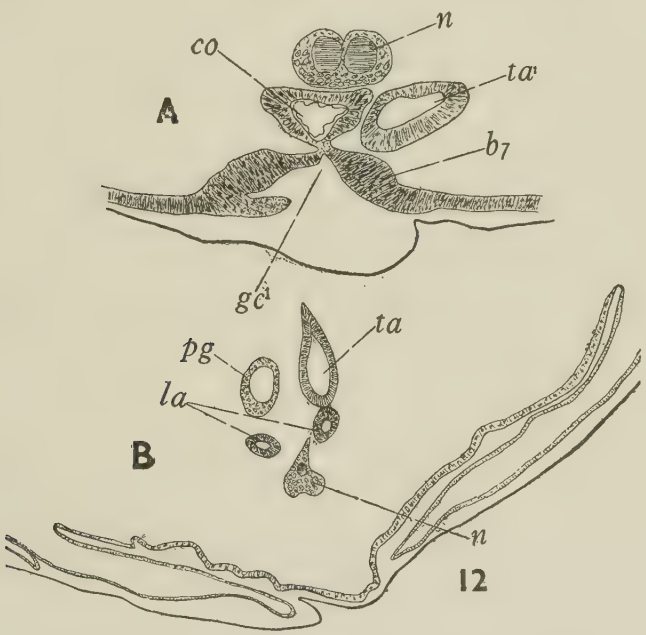

FIG. 12.—*Apis*. A. T.S. of a prepupa to show the developing common oviduct; B. the same showing the lateral arms (*la*) of the common oviduct.

basal part. A second median invagination arises from between the bases of the anterior valves, on the apex of which are present a pair of papilla-like outgrowths. During subsequent development these papillae become the associated tubular glands of the spermatheca, and the globular sac becomes the spermatheca proper. The common oviduct arises as a broad median groove a little posterior to the imaginal discs of the seventh segment. The terminal ampullae still rest on their respective imaginal discs and their cells spread out posteriorly.

In the early prepupa a little anterior to the invagination of the acid gland another median invagination arises which is the rudiment of the alkaline gland. The body wall between the invagination of the spermatheca and that of the common oviduct becomes sunken. This is the beginning of the genital chamber. The lower lips of the groove of the common oviduct (*co*) meet anteriorly and the terminal ampullae (*ta'*) come to lie on either side of the apex of this rudimentary oviduct (fig. 12, A), and at the same time a distinct inner chitinous lining

becomes apparent. The imaginal discs of the seventh segment are no longer visible as separate structures but merge with the subgenital plate which is formed by the seventh sternum. The rudiments of the spermatheca and the common oviduct become more approximated by the shrinking of the intervening ectoderm than in the previous stage. The acid gland is better developed and the oviducts acquire a lumen.

In the late prepupa there is a further shrinkage of the ectoderm which lies between the common oviduct and the spermatheca and a further deepening of the genital chamber. This process progresses further until in the early pupa the two rudiments become contiguous. In the late prepupa the apical part of the acid gland bifurcates at its tip. These branches become the acid gland proper in the adult. The poison sac acquires a chitinous intima. The development of the ovaries and spermatheca is arrested in the prepupal instar and the common oviduct receives a chitinous intima.

Anteriorly, in the early pupa the common oviduct undergoes important changes. A median longitudinal constriction, which starts from the dorsal and ventral surfaces, divides its anterior end into two short lateral ducts (*la*) with blind anterior ends. Associated with these blind ends are the ampullae of their respective sides (fig. 12, B). At a later stage communication between them is established by the disappearance of the intervening walls. No displacement of the mesodermal oviducts by the ectoderm takes place. The various structures of the efferent system, by further histological differentiation and growth, attain during this instar the form found in the imago.

Conclusions.

In the earliest larvae of the Symphyta (*Cephus*, *Nematus*, *Phymatocera*) buds of the genitalia are absent. They are first evident in the sawflies *Nematus* and *Phymatocera* when the larva is in its third instar, and in *Polemon*, *Nemeritis* and *Pteromalus* when the larva is still very young, probably in the second instar. The buds are then situated on the surface but become sunken later in development into hypodermal pockets (peripodial cavities). The higher members of the order, viz. *Apis mellifica* and *Vespula germanica*, show that the buds are present in the earliest larval instar and arise as evaginations of the peripodial cavities.

A pair of buds is present on each of the eighth and ninth sterna. Those of the eighth are more widely separated from each other than those of the following segment (*Cephus*, *Nematus*, *Phymatocera*, *Polemon*, *Vespula* and *Apis*), while they are situated equidistant from each other on both segments in *Pteromalus* and *Nemeritis*. During subsequent development each bud on the ninth segment divides into an inner and an outer part. With further development those on the eighth become the ventral valves, the inner pair on the ninth fuse and form the sheath or inner valves and the outer pair become the palp-like dorsal valves. The present ontogenetic study shows that there is a variance in the relative position of the imaginal discs, and if this argument is considered alone, then the interpretation of their homology becomes difficult. The reason why the buds on the eighth segment are more widely separated from each other than those of the ninth segment can be explained as follows.

(1) In all the forms where the buds of the ventral valves are more widely separated from each other than those on the ninth segment, it is seen that the first structure to arise is the accessory gland (in the sawfly) or the acid gland (in

Polemon, *Vespula* and *Apis*) from the bases of the inner valves. Hence these must necessarily move towards the median line first.

(2) In *Nemeritis* and *Pteromalus* where the buds on the two segments are equidistant, it is found that they move in the median line simultaneously and the development of the spermatheca and acid gland occurs at the same time. The former form the bases of the ventral valves and the latter form those of the inner valves. The above two arguments lend support to the previous contention that the development of a structure from the bases of the valves can influence the relative position.

(3) If the posterior region of a larva is examined it is seen that each anterior segment is larger in diameter than the one following. Naturally the buds are proportionately located, thus making the proportionate disparity in their position obvious. Finally if one examines a caterpillar one finds that at least the last pair of abdominal legs are situated nearer each other than any other pair. Yet all the abdominal legs are considered of the same nature.

From the above argument it seems reasonable to conclude that the relative position of the buds can be influenced by the origin of structures from their bases, and that the distance between each pair of buds on each segment is in proportion to the size of the segment. Therefore, for a correct interpretation of their homology, the mode of origin and subsequent growth and differentiation are the main factors to take into account.

The accessory plates that are associated with the female genitalia, namely the triangular and the oblong plates, have been designated by Snodgrass (1935) the first and second valvifers, homologous to the coxites of the eighth and ninth segments of a Thysanuran. My observations on *Vespula* and *Apis*, and those of Zander on *Apis*, show that they represent remnants of the eighth and ninth sterna. Hence there is a possibility of their representing coxosterna instead of coxites alone.

From the foregoing account the following conclusions may be drawn.

(1) The ventral and inner valves are homologous structures and represent the gonapophyses of the eighth and ninth segments.

(2) The dorsal valves represent laterally drawn-out coxites of the ninth segment having no counterpart on the eighth segment.

Among other insects the recent investigations of Walker (1919) and Snodgrass (1933) on Orthoptera, Metcalfe (1932a) and Rawat (1939) on Hemiptera, George (1928) on Homoptera and Zygoptera are in complete agreement with my conclusions on the nature of the valves of the ovipositor. Observations by Nel (1929) on *Locustana*, *Colemania* and *Blatella* suggest that the ventral and dorsal valves are homologous structures and of the nature of coxites, while the inner valves alone represent gonapophyses of the ninth segment. Nel cited evidence from the work of George (1928) on *Agrion* (Zygoptera). The latter author described and figured in connection with the ventral valves a pair of median processes, which Nel stated can be regarded as homologous to the inner valves and, therefore, represent gonapophyses of the eighth segment. The fact that George himself neither designated them nor discussed their homology but considered them unique in insects, indicates his doubts about the nature of these structures. In my opinion, if Nel's argument is to be accepted at all, this should not be done until a large number of insects are shown to possess structures similar to those present on the ventral valves of *Agrion*.

In addition to the above forms in which the development of the buds is traced up to the adult condition, full-grown larvae of the following were

examined: Braconidae—*Alysia manducator* and *Microgaster*; Ichneumonidae—*Collyria calcitrator*; Formicoidea—*Acanthomyops niger*; Sphecoidea—*Sceliphron* sp. All showed one pair of buds on the eighth sternum and two pairs on the ninth.

It may therefore be concluded that in the Hymenoptera the parts of the ovipositor are derived from the eighth and ninth abdominal segments. This is in complete agreement with the opinion of investigators of other orders of insects which possess an ovipositor.

Efferent genital system.

Kraepelin (1873), Dewitz (1877), James (1928) and Zander (1916) all state that the common oviduct arises from imaginal discs. This contention receives no support from my study and it has been clearly shown that the imaginal discs or buds in question merge with the subgenital plate (seventh sternum) in course of development. Furthermore in the sawflies these buds do not appear. Finally the recent workers Tiegs (1922) and George (1934, 1935) do not record the presence of the buds taking part in the formation of the common oviduct.

Among the other orders of insects Dodson (1935), working with *Brachycentrus* (Trichoptera), is the only author who notes the origin of the anterior region of the common oviduct from ectodermal thickenings present on the seventh abdominal segment. It may be true for the Trichoptera which show other differences as well.

In the Hymenoptera the mesodermal oviducts run from the ovaries up to the seventh abdominal sternum, where they end in swollen ampullae. This is in complete agreement with the earlier investigations of Carrière and Bürger (1897), Zander (1916), George (1935), etc. The common oviduct in all the forms arises as a median invagination from the hind margin of the seventh sternum. In *Nematus*, *Nemeritis*, *Pteromalus* and *Apis* the apical end of this invagination becomes divided into two short arms into which open the ampullae of their respective sides. In *Polemon*, *Vespula* and *Prosopis* no such division takes place but the ampullae open directly into the end of the common oviduct. Zander (1916) in *Apis mellifica* and George (1934, 1935) in *Melipona iridipennis* and *Apis indica* also describe a similar differentiation of the anterior end of the common oviduct. Observations by Zander also indicate that the posterior parts of the mesodermal oviducts are replaced in subsequent development by encroachment of ectodermal cells from the common oviduct. George found no ground to agree with Zander's conclusions, nor do Zander's conclusions receive support from the present study. Finally the earlier workers Kraepelin, Seurat, etc., do not mention any such replacement in their accounts.

Spermatheca or receptaculum seminis.

The spermatheca in all the forms arises as a median invagination from the bases of the ventral valves and later becomes differentiated into three regions.

(*a*) An apical glandular part.
(*b*) A vesicular part or spermatheca proper.
(*c*) A conducting duct.

Although Seurat (1899) in *Doryctes* observed the spermatheca arising as an evagination of the vagina, recent studies by Zander (1916) and George (1935) support my conclusions. While they both maintain that this structure arises from the bases of the ventral valves, they, however, differ in their view as to the manner of its origin. Observations by Zander appear to indicate that it

originates from paired rudiments. This argument I do not support. The former author is in complete agreement with me. From what has been said above it may be concluded that in the Hymenoptera the mode of origin and position of the spermatheca seem to be constant, and that the spermatheca arises as a median invagination from the bases of the ventral valves on the eighth sternum.

Approximation of the common oviduct and spermatheca (fig. 13, A–D).

Zander (1916) stated that the common oviduct which arises from the seventh abdominal segment is extended on to the eighth by a groove which

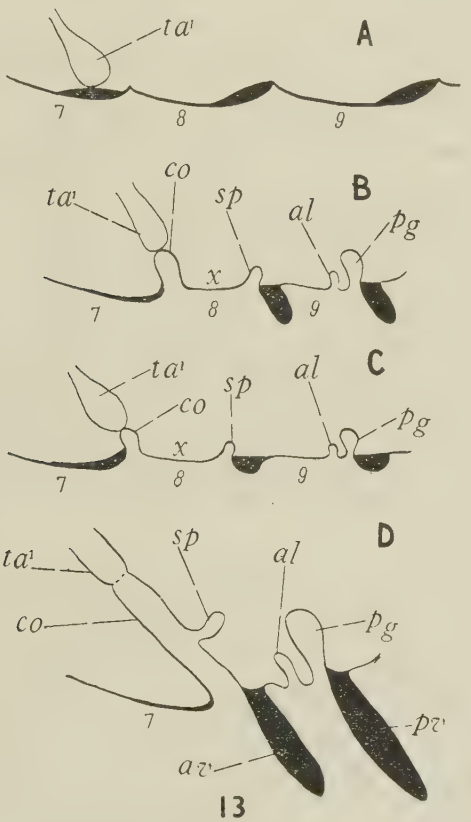

FIG. 13.—A–D. Schematic figures to explain the approximation of the common oviduct and the spermatheca in successive stages of development.

proceeds from this rudiment behind, and a similar groove proceeds anteriorly from the spermatheca. These two grooves meet, their ventral margins fuse, and their anterior connection is lost, thus the female orifice is extended on to the eighth segment. It has been definitely shown that the approximation of these two structures is brought about by the shrinking of the intervening wall and the deepening of the genital chamber and is aided by the telescoping of the hinder segments into the more anterior ones. Christophers (1923) in the mosquito and George (1934) in *Melipona* (Hymenoptera) find that the rudiments

of the spermatheca and the common oviduct become contiguous by a similar process. George in his later publication (1935) failed to note how this is brought about in *Apis indica*. In the account of the former paper George states that the common oviduct arises from the anterior margin of the eighth segment and the spermatheca from behind the ventral valves. Yet his fig. XI, which is a longitudinal section of a fairly advanced prepupa, clearly shows both these structures anterior to the ventral valves. Further, figs. VIII to X (Pl. II) of his later publication strongly uphold the view put forward by me, and it is difficult to understand how George could have failed to describe the process.

Accessory glands.

In the Apocrita two types of accessory glands are generally present—the acid (poison) and the alkaline (gland of Dufour) gland. Investigations by Zander (1916), George (1935) and myself show that the acid gland arises as a median invagination from the bases of the inner valves. A little anterior to this invagination arises the rudiment of the alkaline gland also as a median invagination and these two rudiments retain independent orifices even in the adult. A typical acid gland consists of three portions.

(1) A pair of associated glands (as seen in *Polemon*, *Nemeritis*, *Vespula*, *Prosopis* and *Apis*) or there may be only a single gland (as seen in *Pteromalus*).

(2) A middle vesicular part or the poison sac, which may be muscular as is the case in *Polemon* and *Vespula* but usually non-muscular as in the other forms.

(3) A conducting duct which opens at the base of the inner valves.

In the sawfly *Nematus* only a single accessory gland is present which arises from the base of the inner valves. Therefore this structure from its mode of origin appears to be homologous with the acid gland. In addition to the above structures the glandular pouches in connection with the vagina of *Pteromalus* have already been discussed in the account of the development.

Position of gonopore.

Nematus, *Polemon*, *Vespula*, *Prosopis* and *Apis* all show that the functional female orifice is situated anterior to the ventral valves. As has been shown in the ontogenetic account, the entire region posterior to the invagination of the common oviduct on the seventh sternum and anterior to the rudiment of the spermatheca is depressed to form the genital chamber. This opening of the genital chamber is designated the vulva by Snodgrass (1933), the openings of the spermatheca and common oviduct being situated inward. The position of the common oviduct orifice has, therefore, shifted posteriorly, for certainly the vulva is more posteriorly placed than would have been the orifice of the common oviduct, if the latter structure had not been drawn inwards. It has been said that in the ichneumon, *Nemeritis*, and the chalcid, *Pteromalus*, the functional female opening is placed posterior to the ventral valves. This is incompatible with the general view concerning the posterior shifting of the gonopore, for it is in the higher member of a particular order that it is more posteriorly situated. If this hypothesis is correct then the opening should be located more posteriorly in the Apoidea and Vespoidea than in the Ichneumonoidea or Chalcidoidea. But actually one finds a contrary condition. This may be explained as follows.

If the ovipositor of the insects in question (*Nemeritis* and *Pteromalus*) be examined it will be observed that it is placed more anteriorly on the abdomen than the ovipositor of the bee or wasp. In other words, there has been a for-

ward shifting of the ovipositor in these two insects and, probably, this has been responsible for the posterior situation (posterior to the ventral valves) of the opening which probably involves a case of specialisation in these forms.

Summary.

The foregoing study of female Hymenoptera shows that the ventral valves of the ovipositor develop from the eighth segment, the posterior and lateral from the ninth. The ventral and posterior valves are regarded as homologous, and the lateral valves represent the greatly drawn-out coxites of the posterior valves. The mesodermal oviducts end in ampullae on the seventh sternum. The following structures arise as median invaginations: the common oviduct from the hind margin of the seventh sternum, the acid gland from the bases of the posterior valves, the alkaline gland from a region anterior to that of the acid gland, and the spermatheca from the bases of the ventral valves. In *Nematus*, *Nemeritis*, *Pteromalus* and *Apis* the anterior end of the common oviduct becomes divided into two short ducts into which the oviducts open.

The approximation of the common oviduct and the spermatheca is brought about by the shrinking of the intervening wall and the deepening of the genital chamber, and is aided by the telescoping of the hinder segments into the more anterior ones. Christophers (1923) in the mosquito and George (1924) in *Melipona* (Hym.) find that these two structures become contiguous by a similar process. The functional female orifice is situated anterior to the ventral valves. In the ichneumon *Nemeritis*, and the chalcid, *Pteromalus*, the functional female opening is placed posterior to the ventral valves and involves a case of specialisation in these forms. Observations of Zander (1916) on Hymenoptera and Metcalfe (1933) on Diptera show that during the post-embryonic development the ectodermal cells from the invagination of the common oviduct invade the mesodermal cells of the oviducts and gradually replace them. My investigations show that no such displacement occurs, nor do other authors working on the Hymenoptera support this contention.

PART II.—THE MALE

To the systematist in Entomology, the study of the male genitalia is becoming of ever-increasing importance. Most investigators have confined themselves to the study of the copulatory organs of the adult and based their interpretations on them. This has resulted in adopting a multiplicity of terms, and their homologies are rendered difficult. The nomenclatorial systems of the various hymenopterists have been tabulated recently by Clausen (1938), and I do not feel it necessary to repeat this. Incidental references with regard to the situation of the male genitalia rudiments have been made by Dewitz (1875), Kraepelin (1873), Eastham (1929) and others who hold different views with regard to the origin of these structures. Those authors who have studied these organs in detail regard the rudiment of the copulatory apparatus as a pair of imaginal discs, borne by the ninth abdominal sternum. In this connection, Seurat (1899), Michaelis (1900), Zander (1903) and Boulangé (1924) may be specially mentioned. With regard to the efferent ducts in the male, knowledge is scantier still. Kulagin, Seurat, Michaelis and others consider these organs of ectodermal origin whereas Zander (1916) and Bishop (1920) consider them of mesodermal origin. From the above account it is clear that the study of this problem from the developmental point of view is far from complete and the following is an attempt to put the problem on a sounder basis.

Cephus pygmaeus.

Adult organs (fig. 14, A).

The testes (*t*) are small plum-shaped structures situated dorso-lateral to the gut in the fifth segment. They are attached to each other along their inner margins. The vasa deferentia (*vd*) run posteriorly and ventrally a short distance, then dilate into seminal vesicles (*vs*) which are normally full of sperms. Each vas deferens in its course is joined by a large sac-like accessory gland (*ag*) and continues posteriorly and joins the one from the opposite side into an ejaculatory duct which opens at the base of the penis.

The genitalia rest on the ninth sternum or hypandrium. They consist of a basal ring (*b*), a pair of outer claspers (*oc*), a pair of inner claspers (*ic*), and a

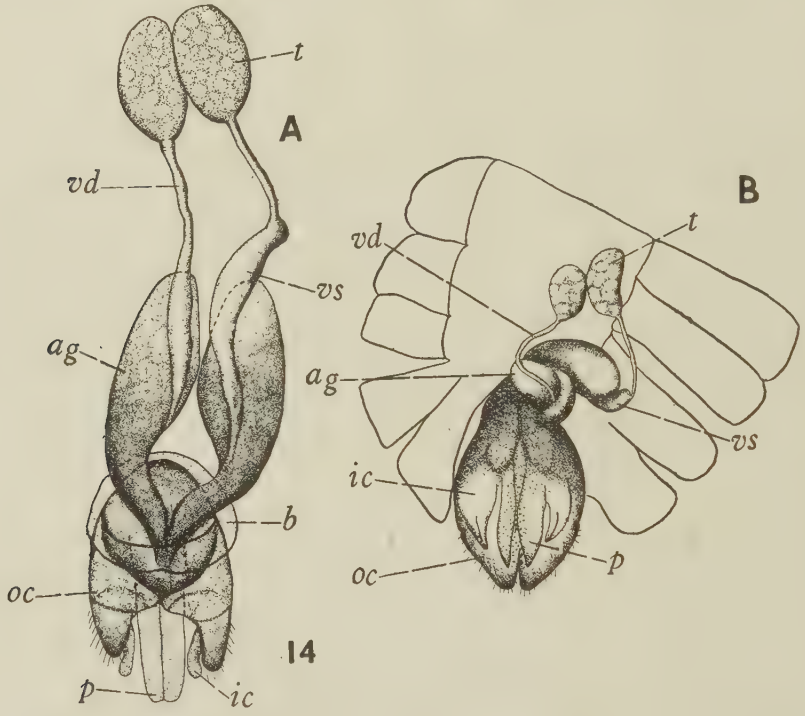

Fig. 14.—Dorsal view of male reproductive organs of A. *Cephus pygmaeus*; B. *Nematus ribesii*.

penis (*p*). The claspers are each differentiated into an apical and a proximal portion. The apical portions of the inner claspers lie at right angles to their basal portions. The apical portions of the outer claspers are furnished with hair. The penis lobes are elongated structures fused along the median line.

Nematus ribesii.

Adult organs (fig. 14, B).

The reproductive organs of *Nematus ribesii* have not been described. There are two oval testes (*t*) which lie, their inner margins touching, above the gut.

The vasa deferentia (*vd*) are of a uniform thickness and dilate towards their basal ends into the seminal vesicles (*vs*). At about this level each vas deferens is joined by an accessory gland (*ag*). The accessory glands and the seminal vesicles are present in a twisted condition, which is brought about by the inversion of the genitalia; indeed, had it not been for the presence of the gut, all the internal reproductive organs would have changed places.

The genitalia are present in an inverted condition. They consist of a basal

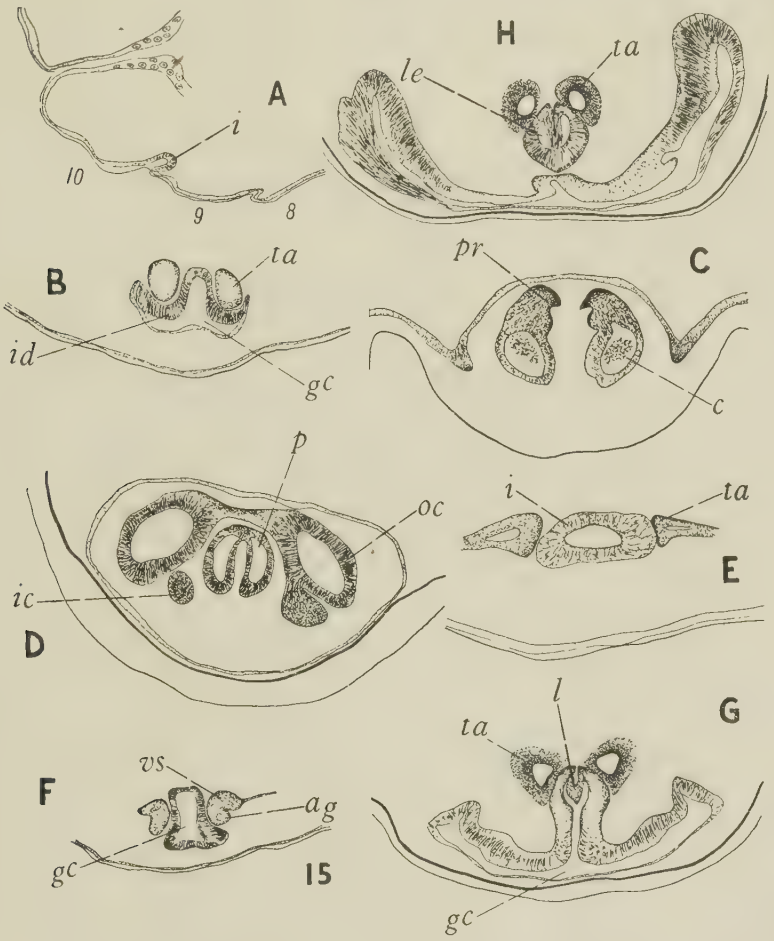

Fig. 15.—A. L.S. first instar larva of *Cephus pygmaeus* showing the point of origin of the median invagination (*i*) between the 9th and 10th segments; B. T.S. of full-grown larva of *C. pygmaeus* showing the buds of the genitalia (*id*), terminal ampullae (*ta*) and the genital chamber (*gc*); C. T.S. of an early prepupa of *Nematus ribesii* showing the development of the rudiments of the penis (*pr*); D. T.S. of a late prepupa of *N. ribesii* showing the development of the claspers; E. T.S. of a first-instar larva of *C. pygmaeus* showing the relation of the median invagination (*i*) and the terminal ampullae (*ta*); F. T.S. of a full-grown larva of *C. pygmaeus* showing the differentiation of the seminal vesicles (*vs*) and the accessory glands (*ag*); G–H. T.S. of successive prepupal instars of *N. ribesii* showing the deepening of the depression (*l*) until, fig. H, two separate ducts (*le*) are formed.

ring by which they are connected to the hypandrium (IXth sternum). On this is borne a pair of outer claspers (*oc*) each of which is two-jointed. More dorsal to this and posterior to the penis are the inner claspers (*ic*). Each of these is also a two-jointed structure with its apical part flattened and lying more or less at right angles to the basal part. The penis (*p*) is a simple structure composed of two lateral plates which are bifid at their tips and produced proximally as apodemes on which the penial muscles are attached. The two plates are connected mostly by a membrane.

The development of the genitalia and the efferent system in *Cephus* and *Nematus* agree closely and the following account is common to both.

Development of genitalia.

The first-instar larva shows a median pocket-like invagination on the ventral side between the ninth and tenth segments (*vide* fig. 15, A). When the larva is in its penultimate instar a pair of imaginal discs (*id*) arise from the antero-lateral wall of this invagination and hang freely in it (fig. 15, B). In a full-grown larva the discs shift dorsally and enclose a groove between them. The penis rudiments (*pr*) arise in the early prepupal stage as meso-dorsal evaginations from the basal part of each imaginal disc (fig. 15, C). At a later prepupal stage the inner claspers (*ic*) arise from the undivided stems of the disc. They arise ventral to the penis rudiments and more posterior to them (fig. 15, D).

In the pupal instar the main parts of the adult genitalia, developed during the previous instar, continue their growth, and sclerotisation sets in. The penis rudiments fuse farther along their dorsal border to form the penis which is free along its posterior half. The ectoderm on the ventral and lateral base of each imaginal disc grows and forms a semicircular ring; this becomes the basal ring. The outer claspers become differentiated into basal and apical parts; similarly the inner claspers.

Efferent system.

In a very young larva the testes lie dorso-laterally to the gut in the fifth segment and the vasa deferentia extend postero-ventrally, ending in hollow terminal ampullae (*ta*) resting on either side of the invagination of the genitalia (fig. 15, E). The ampullae increase in size during subsequent larval instars and in the full-grown larva they lie in the hollow of their respective imaginal disc (fig. 15, B). At a very late, full-grown, larval stage an anteriorly directed outgrowth arises from each ampulla which is the rudiment of the accessory gland (*ag*) and the undivided basal swollen end of each becomes the seminal vesicle (*vs*) (fig. 15, F). The ejaculatory duct arises from the median groove enclosed between the discs. During the prepupal stage the groove of the ejaculatory duct deepens and its dorsal apical wall becomes depressed (fig. 15, G), while the ends of the vasa deferentia move and lie in association with them. In the early pupal stage the apical tongue-like depression (*l*) of the ejaculatory duct deepens and divides its apical end into two lateral arms (*le*) into each of which later opens the vas deferens of its side (fig. 15, H). The adult structures are completed and further development results in their growth and histological differentiation.

Polemon liparae.

Adult organs (fig. 16).

The testes (*t*) are large globular structures situated ventro-lateral to the gut between the seventh and eighth segments. Each vas deferens (*vd*) is a short

and thick tube which runs backwards and dilates into a seminal vesicle (*vs*) which is joined on its posterior end by the accessory gland (*ag*) of its side and opens into a median ejaculatory duct (*e*) opening outside by the genital pore situated at the base of the penis. The accessory glands are large anteriorly twisted structures. The ejaculatory duct, the vasa deferentia and the accessory glands are encased in a muscular lining.

The genitalia (fig. 17, A) consist of a basal ring (*b*), a pair of outer claspers

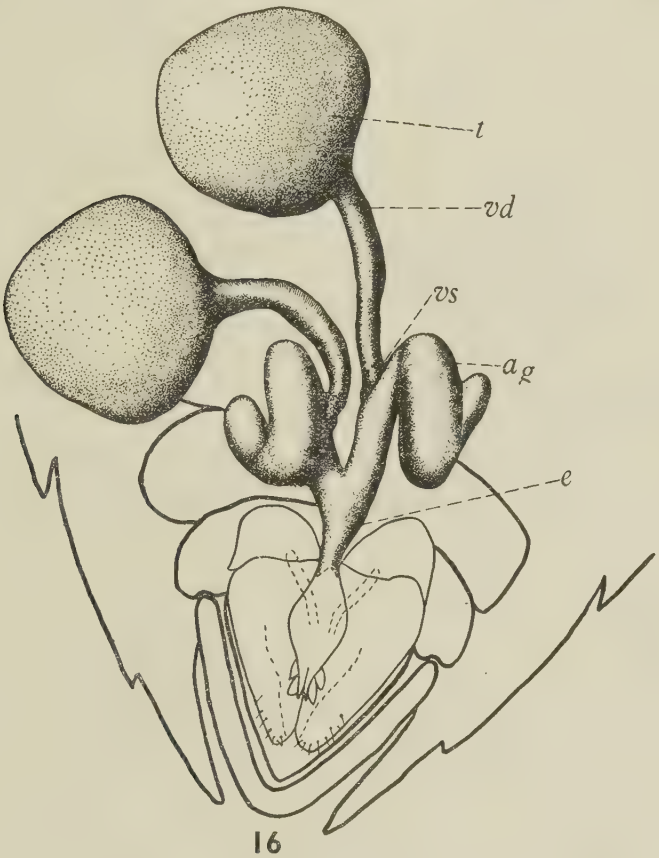

Fig. 16.—*Polemon liparae.* Reproductive organs of adult male (dorsal view).

(*o*) furnished with hair, a pair of inner claspers (*ic*) and a penis (*p*). The inner claspers are each differentiated into an apical part and a basal part. The penis is a lightly sclerotised structure bifid at its posterior end and gives out anteriorly a pair of sclerotised rod-like processes.

Pteromalus liparae.

Adult organs (fig. 17, B).

The testes (*t*) are spindle-shaped and are situated dorso-lateral to the gut in the seventh segment. The vasa deferentia (*vd*) are short ducts which dilate into the seminal vesicles (*vs*) basally before the pear-shaped accessory glands

(*ag*) join them, and continue back to join into the ejaculatory duct which opens outside at the tip of the penis. The ejaculatory duct gives out anteriorly a short conical median diverticulum (*d*). Grandi (1929), in *Blastophaga psenes*, describes a caecum-like tubular elongation of the ejaculatory duct. This structure in *Pteromalus* probably stores sperm for a single complete discharge during copulation.

The penis (*p*) is a cylindrical tubular structure tapering at its apex where the gonopore is situated. Basally it is continuous with the sheath (*oc*) formed by the two outer claspers in which it can be retracted. Its walls are strength-

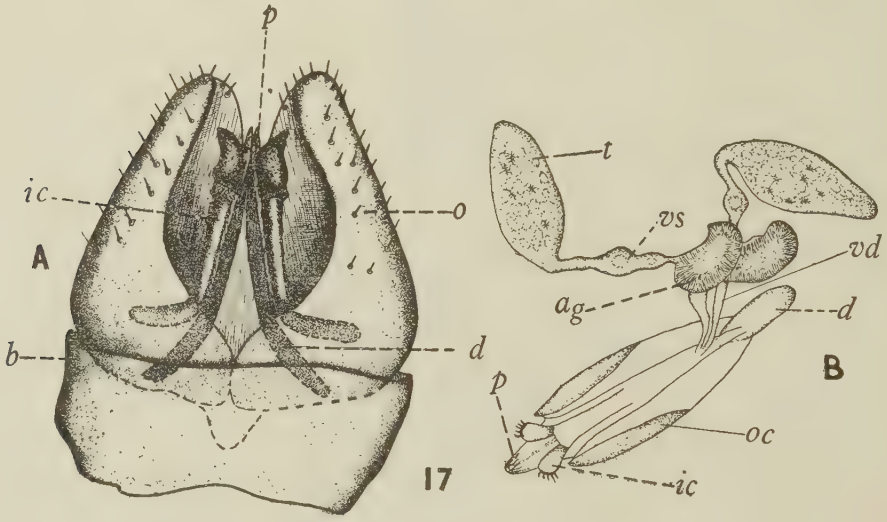

Fig. 17.—A. Genitalia of adult male *Polemon liparae* (dorsal view); B. *Pteromalus liparae*. Male reproductive organs (dorsal view).

ened basally by sclerotised rods which expand anteriorly to about the same length as the length of the penis. There are six pairs of genital papillae at the apex of the penis. Similar structures have been described by Imms (1919) in *Blastothrix*. The inner claspers (*ic*) are lodged on the hinder border of the penis sheath and ventral to it. There are no counterparts of the lateral process at the base of the inner claspers as described by Imms (1919) in *Blastothrix*. Each inner clasper is crowned with five outwardly directed setae.

Polemon and *Pteromalus*.

Development of the genitalia.

A young larva about 1 mm. long showed a pair of ectodermal thickenings close to each other on the ventral side posterior to the ninth segment (fig. 18, A). In *Pteromalus* these thickenings first appear when the larva is 2 mm. long. Subsequent development shows these buds enlarge until in the full-grown larva they become sunken anteriorly over the ninth sternum and get lodged in a genital chamber. During the prepupal stage each of the imaginal discs gives out from its base a backwardly directed mesodorsal outgrowth (*pr*) which is the rudiment of the penis (fig. 18, B). The inner claspers (*ic*) arise during the pupal stage from the main stem posterior to the penis lobe and ventral to them in position, and the penis lobe fuses (fig. 18, C). The basal ring starts

developing in the prepupal instar as a ventral and lateral ectodermal semicircular thickening from the base of each imaginal disc. The counterpart of the basal ring is not developed in *Pteromalus*, but in this form during the pupal instar the outer claspers gradually surround the penis rudiments, which in turn fuse to form the penis (fig. 18, D) and the penis in course of development thus

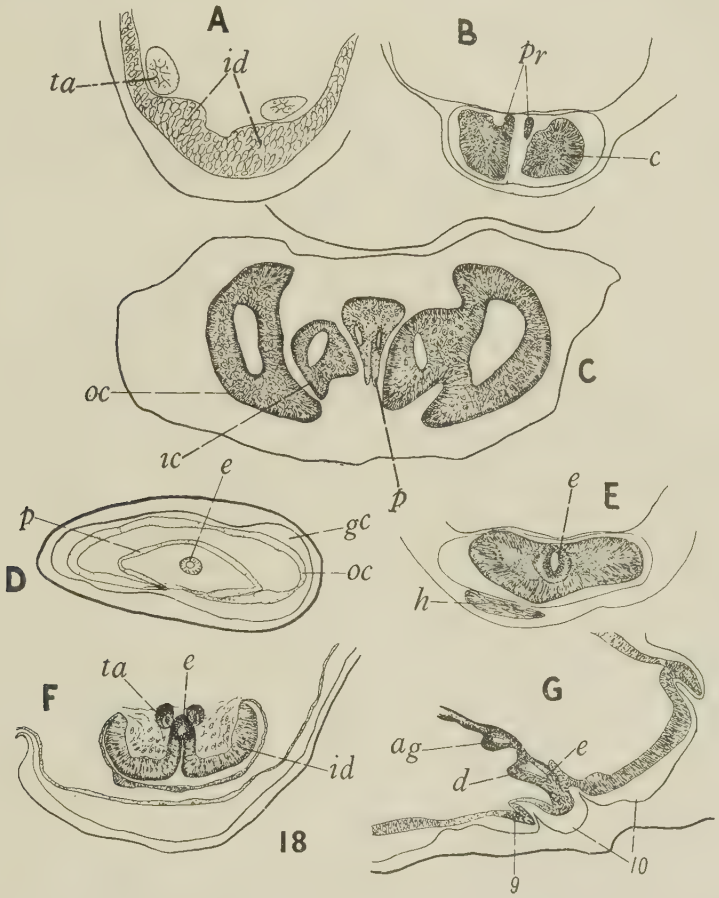

FIG. 18.—A. T.S. of 1-mm.-long larva of *Polemon liparae* showing developing buds of the genitalia (*id*); B. T.S. of a prepupa of *Polemon liparae* showing the development of the rudiments of the penis (*pr*); C. T.S. of an early pupa of *Polemon liparae* showing the development of the inner claspers (*ic*) and the fusion of the penis rudiments (*p*); D. T.S. of pupa of *Pteromalus liparae* showing the condition of the genitalia as seen in the adult; E. T.S. of a prepupa of *Polemon liparae* showing the development of the ejaculatory duct (*e*); F. T.S. of prepupa of *Pteromalus liparae* showing the development of the ejaculatory duct (*e*); G. L.S. of a late prepupa of *Pteromalus liparae* showing the development of the median diverticulum of the ejaculatory duct (*d*).

becomes encased in the surrounding fused outer claspers (*oc*) which then form its sheath. In both insects the penis diverges anteriorly into a pair of arm-like processes.

Efferent system.

The testes lie ventro-lateral to the gut in the eighth segment in larvae 1 mm. long. The vasa deferentia are short and thick with no lumen and extend as far back as the anterior margin of the ectoderm thickenings, where they terminate in comparatively large terminal ampullae (*ta*) (fig. 18, A). Subsequent stages show an increase in the size of the imaginal discs. In the full-grown larva the vasa deferentia acquire a lumen and the imaginal discs basally enclose a groove.

In *Polemon* during the prepupal stage the ventral lips of this groove meet to form a duct which is the rudimentary ejaculatory duct (*e*) into which open later the terminal ends of the vasa deferentia (fig. 18, E). The accessory glands arise as anteriorly directed outgrowths from the outer lateral parts of the ampullae as in the case of *Cephus* or *Nematus*.

In the pupal instar the accessory glands become more and more curved with progressive development and there is further growth and histological differentiation in all the structures. The accessory glands, the ejaculatory duct and the vasa deferentia all become encased in an outer muscular coat and it is at a very late stage that the basal portions of each vasa deferens, at their union with the accessory glands, swell to form the seminal vesicles.

In *Pteromalus* during the early prepupa the ventral lips of the anterior ends of the groove meet, forming a small duct (*e*), and the ampullae (*ta*) shift and become associated with this duct (fig. 18, F). From each ampulla buds out an anteriorly directed accessory gland as in the forms described previously. At a later stage the fusion of the penis rudiments results in the transformation of the groove between them into a tube which is in continuation of the apical duct. This entire duct thus forms the ejaculatory duct into the anterior apical end of which open the vasa deferentia. The structure which has been designated the median diverticulum (*d*) of the ejaculatory duct buds out at this stage from the anterior end of the ejaculatory duct and median to the openings of the vasa deferentia (fig. 18, G).

The pupal stage shows growth and histological differentiation of the various structures.

Vespula germanica.

Adult organs.

The testes lie enclosed in a single scrotum above the gut in the fifth to sixth segments. The vasa deferentia are short and run posteriorly in the mid-ventral line. In the region of the seventh segment each dilates into a proportionately large seminal vesicle and in the region of the eighth segment each is joined on its outer side by a cylindrical accessory gland. The accessory glands are of about the same dimension as the seminal vesicles. Posteriorly the vasa deferentia continue to open into a median ejaculatory duct in the middle region of the penis which opens to the exterior at the base of its spoon-shaped apical end.

For description of the genitalia see Kluge (1895).

Development of genitalia.

Larvae less than 2 mm. long show on the ventral side of the posterior margin of the ninth segment a median thick-walled invagination (fig. 19, A). This invagination grows in subsequent larval stages until it becomes pouch-like and

is the rudiment of the genital chamber. Side by side the anterior dorsal wall of this chamber gradually thickens until in the full-grown larva the imaginal discs (*id*) freely hang in it (fig. 19, B). In the more advanced larva the discs become differentiated into two pairs of structures; the inner are the rudiments of the penis (*p*) and the outer correspond to the undifferentiated claspers (fig. 19, C). The differentiation of the inner claspers (*ic*) occurs in the prepupal instar (fig. 19, D). They arise more posterior and more ventral in position than the rudiments of the penis. The latter structures fuse along their dorsal

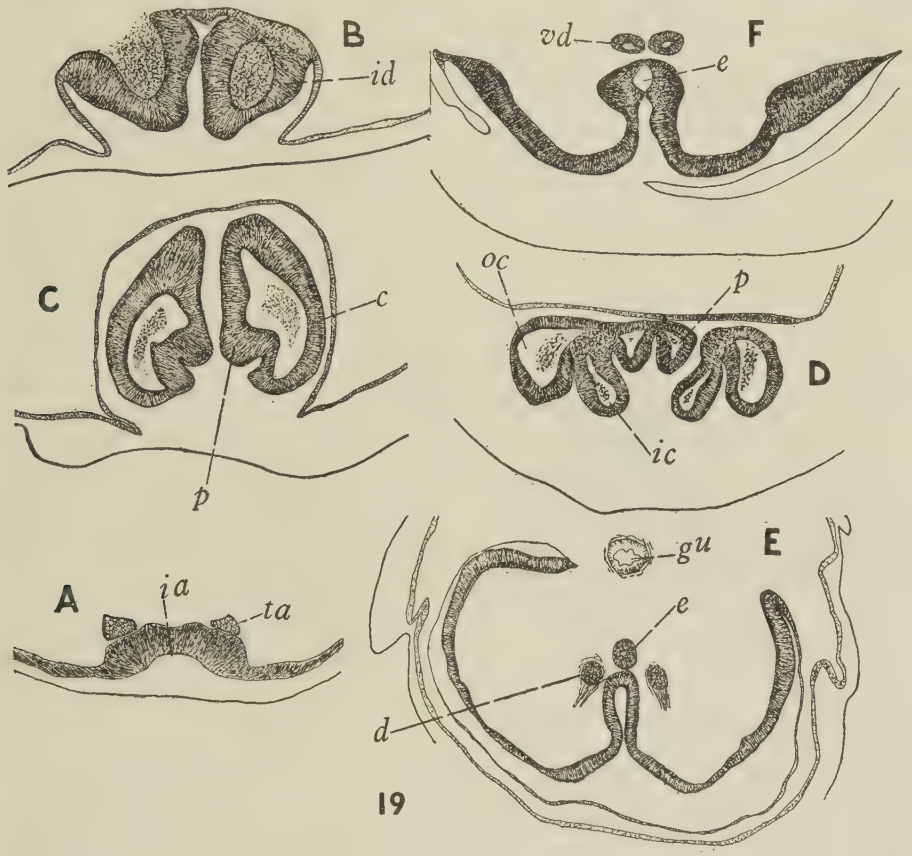

FIG. 19.—A. T.S. of larva (less than 2 mm. long) of *Vespula germanica* showing the developing median invagination (*ia*); B. T.S. of a full-grown larva of *Vespula* showing the fully developed pair of buds of genitalia (*id*); C. T.S. of a late larva of *Vespula* to show the development of the penis; D. T.S. of a prepupa of *Vespula* showing the development of the inner and outer claspers; E. T.S. of an early pupa of *Vespula* showing the development of the anterior processes (*d*) of the penis; F. T.S. of a prepupa of *Vespula* showing the development of the ejaculatory duct (*e*).

anterior two-thirds. The basal ring also arises at this stage from the base of each disc as a thickening of the ventral and lateral walls which take a semicircular shape.

During the early pupa the basal ring develops and the penis gives out anteriorly a pair of rod-like processes (fig. 19, E, *d*). Later pupal stages show growth and sclerotisation of the structures already completed.

Efferent system.

A larva less than 2 mm. long shows the testes situated dorso-lateral to the gut between the fourth and fifth segments. The vasa deferentia extend back in the mid-ventral line as thin solid cords ending in swollen ampullae (*ta*), one on either side of the anterior margin of the invagination of the genitalia (fig. 19, A). Larvae 5 mm. in length show the ampullae with a distinct lumen. The subsequent larval development shows enlargement of the ampullae and in

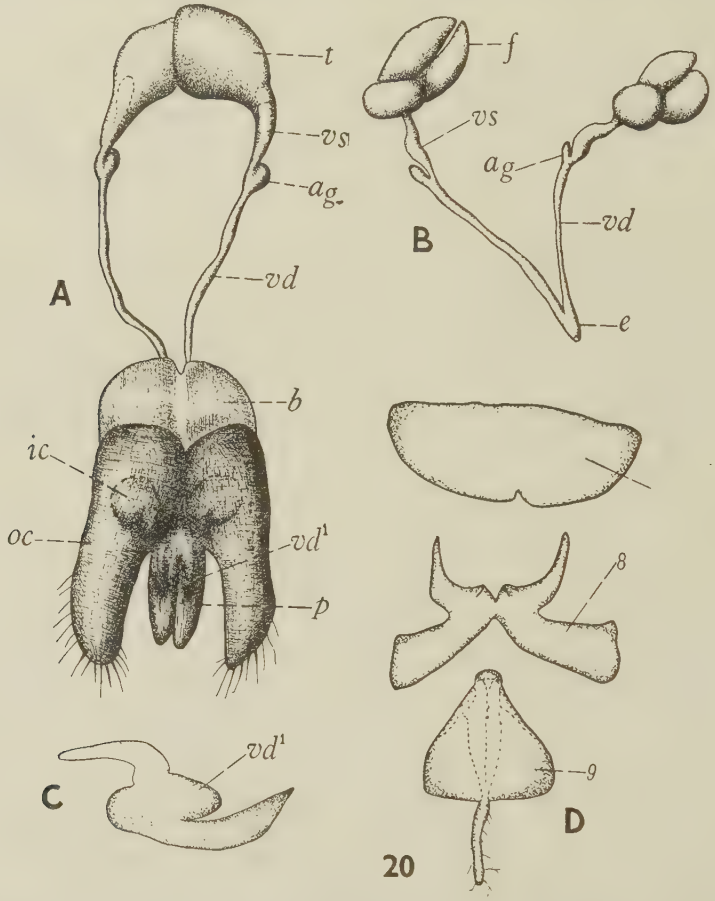

Fig. 20.—A. Adult reproductive organs of *Prosopis krieschbaumeri*, dorsal view; B. Dissection of a late pupa of *Prosopis* showing the forward shifting of the accessory glands and the seminal vesicles; C. Lateral view of the penis of adult *Prosopis* showing the ventral depression (*vd'*); D. Ventral view of the 7th, 8th and 9th sterna of an adult *Prosopis*.

the full-grown larva the vasa deferentia acquire a lumen. At a later, full-grown, larval stage (*vide* fig. 15, F) each ampulla buds out from its outer lateral wall an anteriorly directed outgrowth which is the rudiment of the accessory gland (*ag*) and the inner portions form the rudiments of the seminal vesicles (*vs*). During the prepupal stage the fusion of the anterior lower lips of the penis rudiments begins and progresses posteriorly to form a duct. This is the rudiment of the ejaculatory duct (fig. 19, F, *e*). The vasa deferentia open into the

anterior tip of the ejaculatory duct at a later prepupal stage. Development during the pupal stage results in growth and histological differentiation of the structures so far formed.

Prosopis krieschbaumeri.

Adult organs (fig. 20, A).

The hard parts of the genitalia of various species of *Prosopis* have been figured by Saunders (1882), and Strohl (1908) gives the characteristic features of the genitalia of the family. The study of the internal reproductive organs of the family has been neglected, and those of *Prosopis krieschbaumeri* have not been described. The testes (*t*) lie dorso-lateral to the gut in the fifth segment. Each consists of three follicles encased in a common scrotum (*vide* fig. 20, B, *f*). The two testes are in close contact in the median line. Each vas deferens (*vd*) immediately dilates into a seminal vesicle (*vs*), on the posterior outer margin of which there is a bud-like accessory gland (*ag*). From this region the vasa deferentia continue back with a more or less uniform lumen. They traverse the region of the basal ring and join a short median ejaculatory duct which opens to the exterior on the ventral side of the penis at the base of its ventral depression (*vd'*).

The genitalia consist of a basal ring (*b*) which is broad and semicircular. On this are borne on the outer side the outer claspers (*oc*), strongly sclerotised structures furnished with hair longest on the apical end. The inner claspers (*ic*) are snail-shaped and are borne on the ventral and inner basal margin of the outer claspers, posterior to the attachment of the penis. The posteriorly directed inner ends of the inner claspers are more strongly sclerotised. The penis (fig. 20, C) is a tongue-shaped median structure fused for a short length along its mid region. The posterior half is free and the apices curve downwards. Anteriorly it diverges into a pair of arms to which the penial muscles are attached. On the ventral median part of each half of the penis is a ventrally depressed strongly sclerotised area (*vd'*). These areas merge with the penis proximally and at their point of merging the ejaculatory duct opens.

The posterior sterna (fig. 20, D).

The hypandrium in the adult is formed by the seventh sternum. It is a semilunar structure curved posteriorly. In the middle of its posterior curved margin is a small notch. The eighth sternum lies retracted on the seventh. It is a slipper-shaped structure with its pointed ends directed anteriorly and its flattened ends directed posteriorly and outwardly. The ninth sternum lies overlapping the previous two sterna. It is a shield-shaped structure with the conical end directed anteriorly. A handle-shaped rod which is furnished with hair projects behind from its ventral margin. This part protrudes under the genitalia, and the presence of hair seems to suggest a sensory rôle.

Development of genitalia.

A very young larva slightly longer than the egg (less than 2 mm.) shows a pair of ectodermal thickenings on the ventral median posterior margin of the ninth segment. In successive stages these buds (imaginal discs) enlarge and become sunken anteriorly in a genital chamber. They are thus shifted on to the ninth sternum. In full-grown larvae they are seen to be attached to the anterior dorsal margin of this chamber in which they hang freely (*vide* fig. 19, B). At a later larval stage each disc becomes differentiated into two lobes. The inner

lobes, which are smaller and attached to the inner dorsal wall of the outer, are the rudiments of the penis (*p*), while the outer pair represent the undifferentiated claspers (*c*) (*vide* fig. 19, C). The inner claspers become differentiated during the prepupal stage. They arise from the main stem ventral to the penis rudiments and from a more posterior position (*vide* figs. 18, C, 19, D). The inner

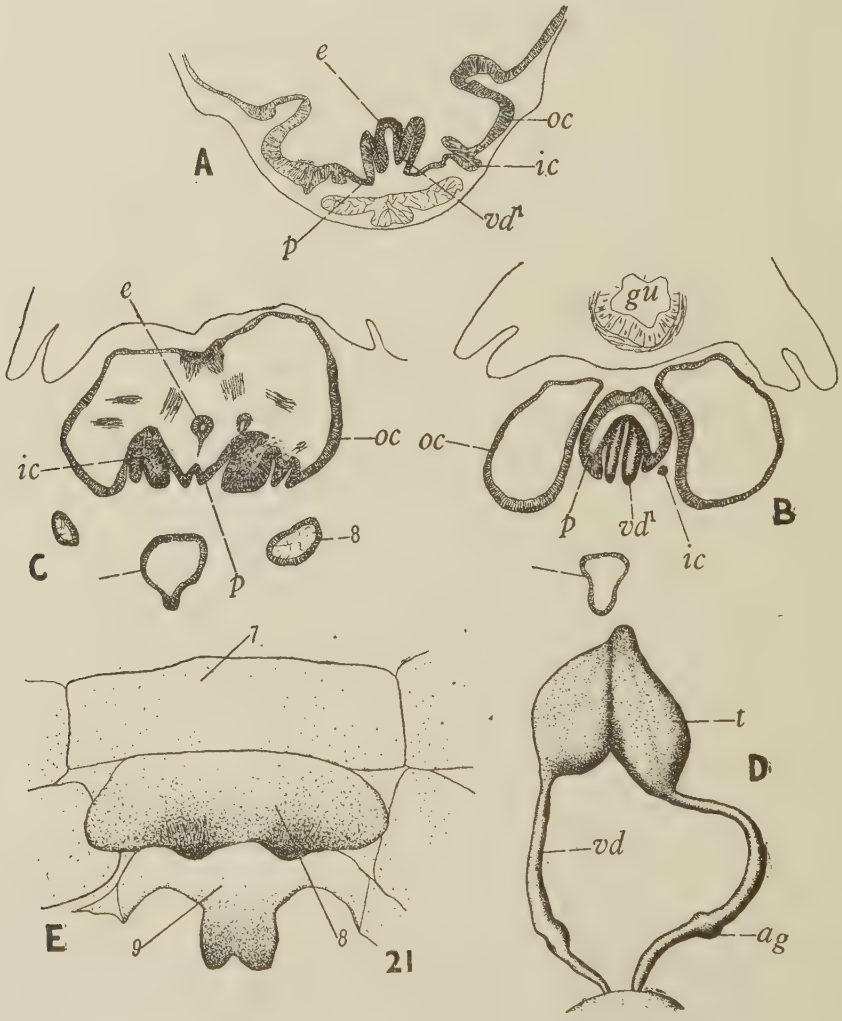

Fig. 21.—A and B. T.S. of a prepupa of *Prosopis* showing the folds of the inner median walls of the penis valves which become the ventral depressions (*vd'*) of the penis valves in the adult; C. T.S. of an early pupa of *Prosopis* showing the developing ejaculatory duct (*e*); D. Reproductive organs of a middle pupa of *Prosopis* showing the position of the accessory glands, dorsal view; E. Ventral view of the developing sterna (7th, 8th and 9th) of a prepupa of *Prosopis*.

ventral walls of the penis rudiments on each side become folded basally (*vd'*). These areas after sclerotisation form ventral depressions in the adult while, proximally, the penis rudiments fuse (fig. 21, A, B). The ectoderm on the ventral and lateral base of each disc grows and forms a semicircular ridge. This

is the rudiment of the basal ring. During the pupal instar each half of the penis gives out an anteriorly directed process (as in *Vespula*, fig. 19, E, *d*). Growth and sclerotisation of the different structures then take place.

Efferent system.

Young larvae less than 2 mm. in length show the testes lying dorso-lateral to the gut in the fourth segment. The vasa deferentia extend back as thin solid cords towards the mid-ventral line and end in hollow ampullae (*ta*) which are situated on the posterior border of the imaginal discs (as in fig. 18, A). Subsequent larval development shows enlargement of the ampullae and in full-grown larvae the vasa deferentia begin to acquire a lumen which starts from their posterior ends.

In the prepupal stage the distal portions of the vasa deferentia elongate so that the ampullae are shifted proximally. At this stage the ends of the vasa deferentia are situated at the proximal end of the ventral depression of the penis and the vasa deferentia acquire a lumen.

In the early pupal instar the vasa deferentia open into the anterior tip of the groove which is enclosed by the ventral depressions of the penis. At a later stage the ejaculatory duct (*e*) is formed by the fusion of the anterior ventral lips of the ventral depressions (fig. 21, C).

In the middle pupal instar the accessory glands (*ag*) arise from the outer walls of the ampullae as outgrowths, and their inner swollen portions are the rudiments of the seminal vesicles (*vide* fig. 15, F).

In the late pupal stage the vas deferens and ejaculatory duct acquire an outer muscular lining and there is growth and histological differentiation of the structures.

A point of interest in this type is the gradual forward shifting of the accessory glands and the seminal vesicles. Whereas in the prepupa and early pupa these structures are situated near the ejaculatory duct, they gradually move forward in subsequent development as shown in figs. 21, D, 20, B, until in the adult, fig. 20, A, they are found close to the testes.

The posterior sterna (fig. 21, E).

During the prepupal stage the distal part of the ninth sternum, which has a deeply notched apex, protrudes backwards. Subsequent development during the pupal stage shows that the apical notched portion becomes attenuated and fused to form a hand-like end, and the proximal part gradually acquires a shield-shaped appearance. The eighth sternum gives out in the prepupal instar a pair of widely separated short arms which become in due course its outwardly directed distal arms. The proximal part of the eighth sternum projects out as a pair of arms pointing forwards. Simultaneous with this the posterior sterna begin to telescope, the ninth is moved on to the eighth and the eighth on to the seventh, so that in the adult they are found to overlap and become situated under the genitalia. As the eighth and ninth sterna undergo reduction, the seventh shows progressive growth until finally in the adult it takes the rôle of the male subgenital plate or hypandrium.

Apis mellifica.

Adult organs.

The reproductive organ of the male bee have been described by Michaelis (1900), Zander (1916), Bishop (1920), Snodgrass (1925) and others. A brief outline of the structures is all that is necessary here.

The two testes are small and yellowish structures triangular in shape, consisting of a large number of tubules. Each vas deferens proceeds back as a short coiled duct which dilates in the middle region into a long seminal vesicle and continues posteriorly as a short narrow duct which is joined by a sac-like accessory gland of its side to open into the median ejaculatory duct. According

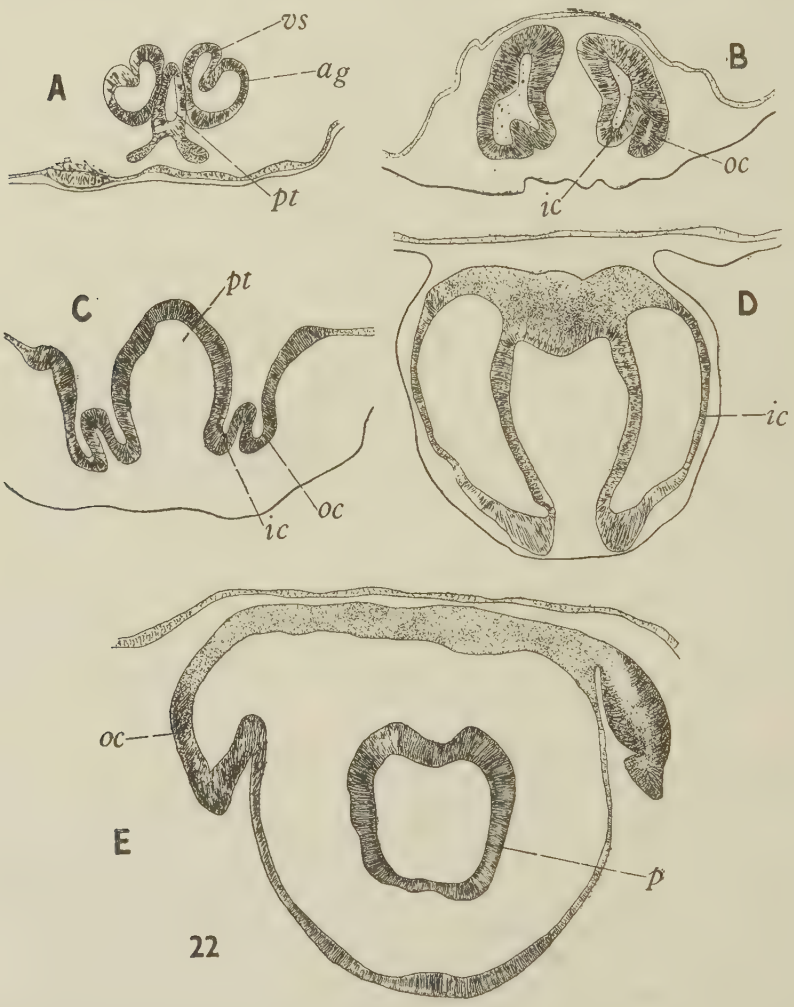

Fig. 22.—A. T.S. of a larva of *Apis mellifica* showing the development of the penial tube (*pt*) and the differentiation of the accessory glands (*ag*) and the seminal vesicles (*vs*); B. T.S. of an early prepupa of *Apis* showing the differentiation of the claspers; C. To show the same as in B. at a more advanced stage; D. T.S. of a very late prepupa of *Apis* showing the inner claspers; E. T.S. same stage as D. to show the position of the outer claspers.

to Snodgrass (1925), the vasa deferentia open into the dorsal wall of the base of the accessory gland of its side. My investigations, as well as the facts of development, are in complete accord with the above observations. The ejaculatory duct which is a long and narrow non-muscular tube reaches as far

as the anterior end of the penis. The ninth sternum forms the male subgenital plate. It bears on each side a pair of claspers. The outer pair, which is darkly sclerotised and furnished with hair, corresponds to the dorsal plate of Snodgrass (1925). The inner pair, which is large and thin and is situated ventral to the outer, corresponds to the ventral plate of Snodgrass. Between the above

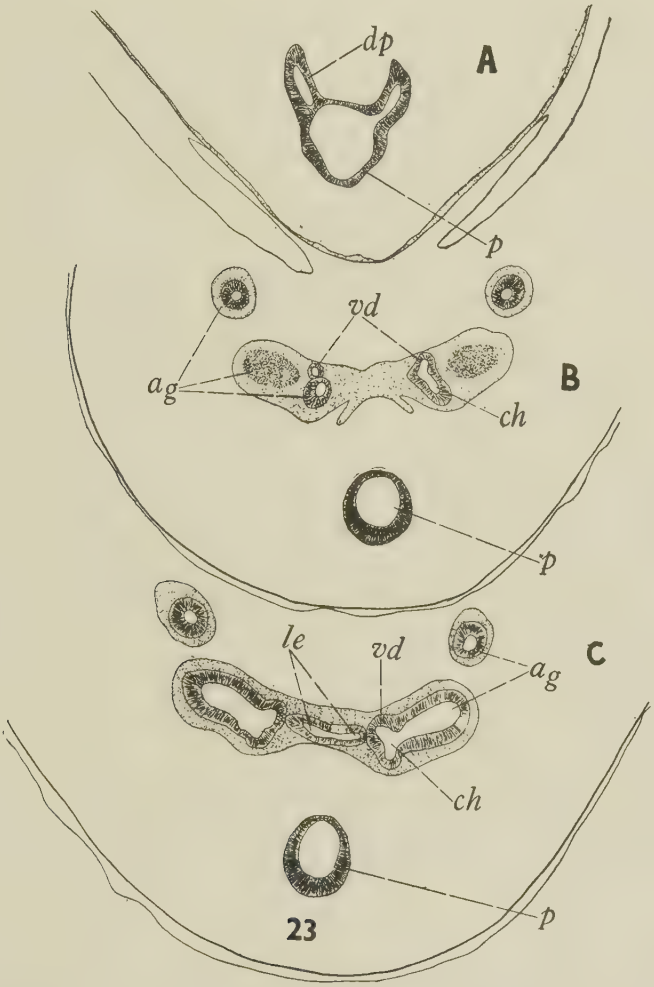

FIG. 23.—A. T.S. of a prepupa of *Apis* showing the development of the dorsal plates (*dp*) of the penis; B. T.S. of a late prepupa of *Apis* showing the relation of the vasa deferentia and the accessory glands; C. Same stage as B. showing the anterior flattened end (*le*) of the ejaculatory duct, *ch* = chamber into which open the vasa deferentia and the accessory gland.

two pairs of claspers is situated the inverted penis, a large structure with complexly modified regions. Its proximal part is enlarged into a bulb with two large sclerotised plates on its dorsal aspect. At the base of the bulb is situated a feather-shaped lobe, the ventral region of which carries a series of

transversely sclerotised plates, and posterior to this region are large areas of dorsal and ventral sclerotisations. The basal part of the penis has a thin wall, to the dorsal side of which are attached two large membranous pouches called the pneumophyses.

Development of genitalia.

One-day-old larvae show a median ectodermal invagination on the ventral surface behind the ninth segment. Subsequent larval development shows gradual increase and deepening in the size of this invagination until it becomes pouch-like and is the rudiment of the genital chamber. Simultaneous with this the anterior dorsal wall of this chamber gradually thickens into the two imaginal discs seen in full-grown larvae (6 days old) to hang freely in the genital chamber (*vide* fig. 19, B). Furthermore at this stage the ventral lips of the groove enclosed between the basal regions of the discs meet, forming a tube (fig. 22, A, *pt*). Two larval stages were sectioned between this stage and the prepupal instar which showed increase and further deepening of this tube, and its differentiation into a large basal portion and a narrow apical portion. The former becomes the penis proper and the latter becomes the ejaculatory duct.

In the prepupal instar a little posterior to the tube and ventral to it, there arise from the inner wall of each disc the rudiments of the inner claspers (*ic*) (fig. 22, B). The remaining parts of the discs form the outer claspers (*oc*). With subsequent development, the tendency of the outer claspers is to move anteriorly and dorsally, so that in a late prepupal stage they become dorsal and anterior to the inner claspers (fig. 22, C, D, E). During the late prepupal stage the proximal part of the penis enlarges to form the bulb, which gives out a pair of hollow outgrowths (*dp*) from its dorsal wall (fig. 23, A). These are the rudiments of the dorsal plates of the bulb of the penis. The dorsal wall of the penis posterior to the bulb gives out a conical outgrowth which is the rudiment of the feather-shaped lobe (double pinnate lobe of Snodgrass, 1925). The wall of the penis ventral to this lobe becomes transversely folded internally, and these folds become the transverse plates.

In the early pupal instar from the base of the penis dorso-lateral in position appear two papilla-like outgrowths, one on either side, which become the pneumophyses.

In the later stages of the pupal instar there is growth and histological differentiation in all the structures so far formed, and sclerotisation of the claspers, the dorsal plates of the bulb, the transversely striated plates and the dorsal and ventral regions posterior to it.

Efferent system.

In one-day-old larvae the testes lie dorso-lateral to the gut in the fourth to sixth segments. The vasa deferentia are thin solid cords which extend back as far as the anterior margin of the rudimentary genital chamber, where they end in hollow ampullae. With further larval development they grow in thickness. In a full-grown larva each ampulla gives out an anteriorly directed outgrowth (*vide* sawfly, fig. 15, F), which becomes the accessory gland (*ag*), while the mesial part becomes the seminal vesicle (*vs*). The anterior narrow end of the penial tube forms the ejaculatory duct. Its origin has already been described in the account of the genitalia. The later full-grown larval stages show the vasa deferentia acquiring a lumen which starts from the basal end and progresses anteriorly.

In the prepupal stage the penis and the ejaculatory duct increase in size and in older larvae show an extraordinary growth. The vas deferens, the accessory glands and the seminal vesicles become surrounded by muscular tissue, and the region of the vas deferens into which the accessory gland of its side joins, enlarges into a small chamber (fig. 23, B, *ch*). The apical end of the

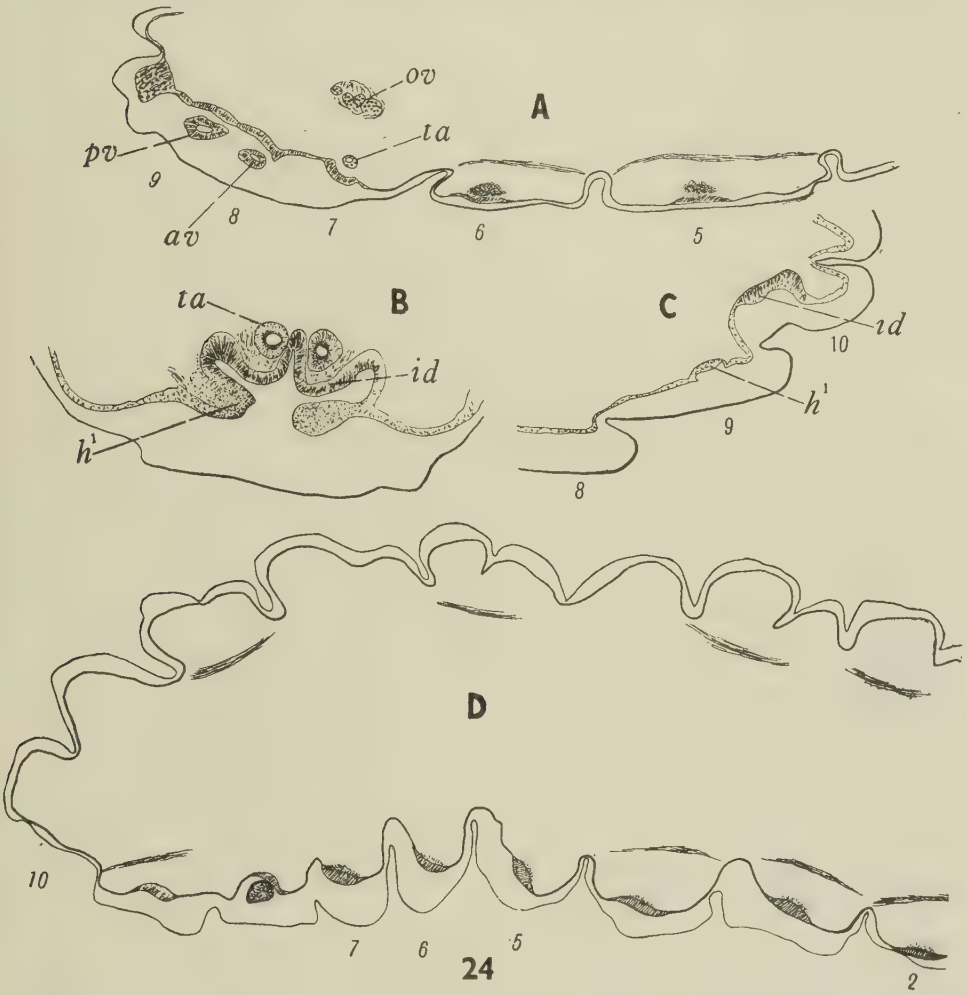

FIG. 24.—A. L.S. of a full-grown female larva of *Polemon liparae* to show the buds on the 5th to 9th abdominal segments; B. T.S. of a late larva of *Polemon liparae* showing the buds of the genitalia and also the additional pair of buds (*h'*) which disappear in development; C. L.S. of a late full-grown larva of *Pteromalus liparae* as in B.; D. L.S. of a full-grown female larva of *Prosopis* to show the buds on the 2nd to the 9th abdominal segments.

ejaculatory duct diverges into a pair of lateral arms, the apical blind end of each of which lies in close contact with the chamber of its side (fig. 23, C, *le*).

In the pupal stage the ejaculatory duct and the penis acquire an internal chitinous lining, but like the vasa deferentia, accessory glands and the seminal vesicles, they are never encased by muscles. Very advanced pupae were

examined and they also did not show connection between the terminal chamber (*ch*) and the ectodermal parts of the ejaculatory duct. Observations of Bishop (1920) show that a communication between these two structures is established prior to copulation.

The Probable Abdominal Appendages.

In recent years the presence of a polypod instar in the development of the parasitic Hymenoptera has been shown to occur in Figitidae by James, in *Ibalia* by Chrystal and in *Phaenoserphus* by Eastham (*vide* Imms, 1937 : 58). My observations on *Polemon liparae* and *Pteromalus liparae* appear to indicate that in the development of these insects a polypod stage is passed. In full-grown larvae of these forms, on the verge of entering the prepupal stage, there appears on each abdominal sternum a pair of ectodermal thickenings. As my work was on the genitalia, only the posterior region of the abdomen was sectioned, but as far as the fifth abdominal segment these thickenings were detected (fig. 24, A). Each thickening had a collection of mesenchymatous cells above it. They were found in both the sexes and they appear at a particular period of development and are short-lived, soon disappearing with the onset of the prepupal stage. The buds of the ovipositor appear to be of a similar nature, for in the female no additional thickenings were present on the eighth and ninth segments besides those of the ovipositor. The thickenings on the seventh sternum in the female persist till a later stage in development and also appear before those of the more anterior segments. This is perhaps due to the response of the underlying cells to the terminal ampullae resting on them.

In the male, these thickenings have been located from the fifth to the ninth abdominal segments. Those of the ninth segment of *Polemon* are large and beak-like (fig. 24, B, *h'*) and those of *Pteromalus* (fig. 24, C, *h'*) are of the same size as the more anterior ones. These buds on the ninth segment in the males I regard as the counterparts of the subgenital plates of Pruthi (1924). These thickenings in both the sexes are more widely separated from each other than those of the genitalia.

In addition to the above two forms, full-grown larvae of *Prosopis kriesch-baumeri* showed similar thickenings on the second to ninth abdominal segments (fig. 24, D). I could get this stage only in the female. Those of the eighth and ninth segments develop into the ovipositor; the rest disappear with the onset of the prepupal instar. The present observations are a preliminary account of the problem and a more complete account is left to the future.

Conclusions.

The account of the development of the genitalia of *Cephus*, *Nematus*, *Polemon*, *Pteromalus*, *Vespula*, *Prosopis* and *Apis* shows that these structures arise as a pair of imaginal discs (" Primitivzapfen " of Zander) surrounded by a depression called the genital chamber or genital pocket. In *Cephus*, *Nematus*, *Vespula* and *Apis* the genital chamber develops between the ninth and tenth sterna prior to the development of the imaginal discs and the discs arise later from its anterior and dorsal inner wall. In the other forms *Polemon*, *Pteromalus* and *Prosopis* the discs are evident first but later become sunken in the genital chamber which arises by the depression of the surrounding wall.

The imaginal discs grow in subsequent larval instars until in the full-grown larva or prepupa each becomes differentiated into a small basal and median portion and a larger lateral portion (figs. 15, C, 18, B). In *Apis mellifica* it is

seen that instead of the differentiation of the single pair into two pairs, a median tube arises from the bases of the imaginal discs (fig. 22, A). This tube has been designated the " Penial tube " (*pt*). During the prepupal instar a second outgrowth develops on the inner side of each imaginal disc. This is situated anteriorly and more ventrally in the first pair and represents the rudimentary inner claspers, as seen in figs. 15, D, 18, C, 22, B. The first pair of outgrowths fuse by their median walls and are the rudiments of the penis. The basal ring begins to develop during the prepupal stage after the differentiation of the three pairs of structures. The ectoderm on the lateral and ventral basal regions of each imaginal disc thickens and forms a sort of semicircular ridge. This reaches completion in the pupal instar and forms the basal ring. This has been observed to take place in *Nematus*, *Polemon*, *Vespula* and *Prosopis*. In *Pteromalus* and *Apis* the differentiation of the basal ring does not occur. Zander (1903) is the only previous author to investigate the development of the basal ring, and his observations on *Vespula germanica* are in complete agreement with mine. The outer claspers may become differentiated into apical and basal parts as in *Cephus* and *Nematus* or no such differentiation may occur, as in *Polemon*, *Vespula* and *Apis*. In *Pteromalus* they spread round the penis and form an encasing sheath for it. Similarly the inner claspers may become divided into basal and apical parts in *Cephus*, *Nematus* and *Polemon* while not in the rest. The penis becomes tubular in *Apis*, but in *Nematus*, *Cephus*, *Polemon*, *Vespula* and *Prosopis* it gives out a pair of anteriorly directed processes designated " anterior processes of the penis." In *Prosopis* the median ventral wall of each penis valve becomes folded. These folds (figs. 20, C; 21, A, B, *vd'*) later become sclerotised, and have been called " ventral depressions of the penis valves " in the present study.

In *Polemon* and in *Pteromalus* it is seen that a pair of buds arise in the middle region of the ninth sternum. These are more widely separated from each other than the imaginal discs of the genitalia. These buds are evident only in grown larvae on the verge of entering the prepupal stage. They are short-lived and atrophy in the prepupal instar (fig. 24, B, C). I am of the opinion that in *Prosopis* the corresponding structures to these are not present, or, if they are, then the elongations of the ninth sternum which form the handle-like posterior end of the sternum in the adult are their counterparts (fig. 21, E.).

The above brief review of the present study shows that the complicated genitalia of adult Hymenoptera can be traced to a single pair of structures.

Peck (1937), Michaelis and Zander agree with me that the rudiments of the genitalia arise from the hind margin of the ninth sternum. Boulangé and others who made observations on full-grown larvae found the rudiments of the genitalia situated on the ninth sternum. It has been shown in the present study that this does happen with the shifting forwards of the genital chamber. Observations of Michaelis, Zander and Boulangé show that the rudiments of the inner claspers are the first structures to arise from the imaginal discs and they are followed by those of the penis valves. It has been shown definitely that they develop in the opposite sequence, and the process is shown diagrammatically in fig. 25, A–C. Hence my investigations are in agreement with those of the above authors in so far as these structures arise from the same pair of buds, but I disagree in the order in which they arise.

I cannot suggest why previous investigators should have overlooked this point, but it has been shown definitely that even in *Apis* the first structure to arise from the imaginal discs is the penial tube and not the inner claspers as alleged by Michaelis and Zander working with this insect.

Recently Snodgrass (1935) has divided the male genital parts of pterygote insects into phallic (inner) and periphallic (outer) structures. The phallic organs consist of the median intromittent organ of the ninth segment, which probably arises from the hind margin of this segment, while the periphallic organs consist of the accessory structures of the ninth or other segments. The penis and parameres are usually regarded as phallic organs and the valvae, harpes, harpagones or claspers as the periphallic organs Typically the phallic structures arise as a pair of buds which later divide into two pairs; the inner pair fuses to form the penis and the outer pair becomes the parameres. This is known as a result of the investigations of Pruthi (1924 and 1924a), Metcalfe

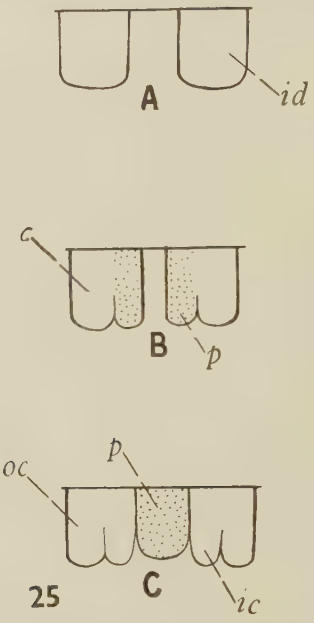

Fig. 25.—Schematic diagram to show the order of differentiation of the penis (*p*) and the claspers from the buds (*id*) of the genitalia.

(1932), Rawat (1939) and others. In the Hymenoptera a similar division occurs, dividing the original pair of buds into an inner and an outer pair. Later from a more posterior position on the outer pair the inner claspers develop. These latter structures are therefore of the nature of endites and appear to have developed in response to the rôle they have to perform in copulation. They have no connection with the rudiments of the penis, but are differentiations from the outer claspers. Hence the inner claspers alone cannot be given the status of parameres but they and the outer together should correspond to the parameres of other orders of insects. This is contrary to the view of some Hymenopterists who regard the inner claspers as the counterparts of the parameres in other orders.

Thus it becomes obvious that in the Hymenoptera typically only phallic organs are present. The periphallic structures are probably represented only in the ontogeny of some forms, viz. *Polemon* and *Pteromalus*. Tiegs (1922) is the only author who differs from the view of previous authors and myself. According to Tiegs, in the Chalcid *Nasonia*, the penis arises as a pair of append-

ages from the tenth segment. The claspers are beak-like and develop from the ninth sternum. It is probable that these beak-like claspers do not correspond to the claspers found in Chalcids, but are of the nature of the subgenital plates of Pruthi, *i.e.*, periphallic structures. If they did, then it would be a unique feature peculiar to *Nasonia*, for claspers in the Chalcids have always been known to form a covering sheath for the penis, as has been shown by Embleton (1904), Imms (1916, 1919), James (1926) and Hanna (1934), and they are never beak-like.

Observations by Wheeler (1893), Tiegs (1922), Else (1934), Roonwal (1937), Sharif (1937) and Rawat (1939) indicate that the phallic structures arise from the tenth segment. I am not in a position to state definitely whether the phallic structures of the Hymenoptera belong to the ninth or tenth segment, as they arise from an intermediate position. If it is maintained, as is done by the above authors, that they belong to the tenth segment, then in the sawfly *Nematus* the abdominal feet on this segment are comparable to the periphallic structures. If on the other hand, as is maintained by Pruthi, Metcalfe, George and others, the genitalia belong to the ninth segment, then the additional buds present on this segment in *Polemon* and *Pteromalus* (*vide* fig. 24, B, C) are comparable to periphallic structures. If the abdominal feet of sawfly larvae are not considered homologous to true appendages, then there is a possibility that the buds of the genitalia represent appendages of the tenth segment, and those on the ninth as seen in *Polemon* and *Pteromalus* represent appendages on the ninth segment. Furthermore, recent observations by Mehta (1933) on the Lepidoptera show that the harpes develop separately from the primary rudiments of the genitalia. The former arise from a pair of thickenings on the ninth segment and the latter from a median outgrowth. More recently Peck (1937), from morphological studies of the genitalia of the Ichneumonidæ (Hym.), is inclined to believe that the squamae (outer claspers) of Hymenoptera are comparable with the harpes of Lepidoptera or the harpagones of Mecoptera. Peck's contention does not receive support from the actual facts of development as shown by the present study, or from the investigations of previous authors on the Hymenoptera. As to the investigations of Mehta, if they are correct, then it appears that the harpes of Lepidoptera correspond to the subgenital plates of Pruthi or the periphallic structures of Snodgrass. The counterparts of the parameres have probably not been differentiated in the forms studied by this author. Recent observations by Metcalfe on *Gastroidea polygoni* and *Anthonomus pomorum* (Coleoptera) also show this simple condition in which the parameres are not differentiated. In this connection it may be pointed out that earlier researches of Zander (1903) are not in agreement with the findings of Mehta. The former author has shown from his investigations on *Paraponyx* (Lepidoptera) that the harpes also develop from the primary pair of imaginal discs. With regard to the contention of Snodgrass (1936) that the penis arises as an unpaired organ, neither my observations nor investigators on other orders, other than Muir (1918) on Coleoptera and Mehta (1933) on Lepidoptera, lend support. In this connection it may be said that other investigators of these two orders of insects are at variance with the above-mentioned authors. Among these Zander (1903) and Verson and Bisson (*vide* George 1928) on Lepidoptera and Pruthi (1924a) and Metcalfe (1932) on Coleoptera may be especially mentioned. Hence opinions on this point are contradictory and only further research can reveal the facts.

As to the question of the anterior processes of the penis valves, *i.e.* the sagittae of authors, the facts of development show that these structures are

modifications of the penis and as they do not arise or remain free structures, they cannot be considered as of the same status as the parameres as some authors maintain. Finally the structures described in *Prosopis* as the ventral depressions of the penis valves are also modifications of the penis. A strong argument that can be advanced against these latter structures representing parameres is that similar structures are absent in *Cephus*, which is a more primitive form. Finally, if one is to give such secondary modifications the same status as parameres, then the homologies would become very difficult, for there are forms which have greatly modified volsellae, viz. the MUTILLIDAE (Vespoidea); there are also forms possessing a secondarily modified penis, *e.g.* some Orthoptera.

From the above discussion the following conclusions seem reasonable.

1. The genitalia of adult Hymenoptera are phallic structures, in the sense of Snodgrass.

2. They arise from a single pair of appendages from the hind margin of the ninth sternum.

3. The penis is comparable with the penis of Coleoptera, Diptera, Hemiptera, etc., as is shown subsequently.

4. The claspers are comparable with the parameres of other orders, such as Coleoptera, Diptera, Hemiptera, as is to be seen subsequently. The inner claspers being mere outgrowths on the outer, of the nature of endites, probably develop in response to their need in copulation.

5. In *Polemon* and *Pteromalus* periphallic structures are represented in ontogeny by a pair of buds on the ninth segment, if it be accepted that the phallic structures also belong to this segment. On the other hand, if it is accepted that the phallic structures belong to the tenth segment as Else, Roonwal, Rawat and Sharif believe, then the abdominal feet, present in the sawfly *Nematus*, are probably comparable with periphallic structures, provided it is admitted, as Imms thinks, that these abdominal feet are remnants of true limbs.

Three views have been advanced to date as to the nature of genitalia.

Walker (1922), Pruthi (1924), George (1928), Bekker (1930) and Metcalfe (1932) regard the primary rudiments of the male genitalia as the endopodites of the ninth segment, homologous with the posterior valves of the ovipositor.

According to the second view the intromittent organ arises as a median outgrowth of the body wall from the hind margin of the ninth segment (Muir, Snodgrass).

According to the third view the genitalia are considered special outgrowths of the ectoderm and are not comparable with the posterior valves. This view further maintains that they arise from a pair of rudiments (" primitivzapfen "), each of which divides into an inner and an outer part. The outer parts become the parameres and the inner parts fuse to form the intromittent organ. Zander is the strongest advocate of this view, and he has found support for it in Trichoptera, Lepidoptera and Hymenoptera. Embryological evidence advanced by Wheeler (1893), Else (1934), and Roonwal (1937) suggests that the genitalia represent abdominal appendages, and the present study is in general agreement with these conclusions.

A review of the genitalia shows that the phallic structures arise from a pair of rudiments among various insects, and become later differentiated. The outer parts of these structures, called parameres, have become forceps-shaped in some, viz. Trichoptera, Hymenoptera, Diptera, etc., and have a clasping function. In others, *e.g.* Orthoptera, Hemiptera, etc., they have retained

a simpler condition. The styli of such insects as the Orthoptera and Ephemeroptera are represented in the ontogeny of some orders, viz. Hemiptera (as shown by Pruthi and Metcalfe), Hymenoptera (as shown by me in *Polemon* and *Pteromalus* or probably the abdominal feet in the sawfly represent them), Coleoptera (as shown by Pruthi and Metcalfe) and Aphaniptera as shown by Sharif. Verhoeff (1903) from morphological studies concluded that the parameres of Dermaptera, Hymenoptera, Coleoptera and Diptera are homologous structures. Very recently Crampton (1938) has also expressed a similar opinion that the genital forceps of the Holometabola belonging to the "forcipate" series (*i.e.* Mecoptera, Trichoptera, Diptera, etc.) are homologous structures comparable with the parameres of Coleoptera and Dermaptera. Finally, Snodgrass (1935) is also of the opinion that the genitalia of the Hymenoptera consist of phallic structures only. Verhoeff goes to the extent of comparing the penis of *Machilis* with the parameres of other insects. Whether such a comparison can be made or not, I am not in a position to give an opinion, especially as so little is known about the development of these structures in the Thysanura. In this connection it may be said that Snodgrass (1936) maintains that the penis in the Thysanura arises as a median organ. If this is true, then Verhoeff's contention cannot be accepted, but the recent remark made by Imms (1937) "that in the Thysanuran *Nicoletia* the penis is slightly bifurcate distally and apparently thus still retains traces of its former double origin," does make one doubt the truth of the opinion expressed by Snodgrass.

Hypandrium.

While the ninth sternum is generally regarded as the last complete sternum in the male, on which the genitalia rest, in the primitive bee *Prosopis* this segment and the eighth have both suffered arrestation of development and lie hidden under the seventh, which is the functional hypandrium in the adult. It is difficult to explain this peculiarity; most probably it is connected with the act of copulation. The seventh being a more anterior sternum, it is larger in size and perhaps gives a better support to the genitalia.

Efferent system.

The vasa deferentia run posteriorly from the testes and terminate in ampullae (*ta*) which abut on the median invagination, which becomes the genital chamber (*gc*) (figs. 15, E; 19, A) or the imaginal discs (*id*) where these are present (fig. 18, A). The accessory glands (*ag*) are the anteriorly directed evaginations of these ampullae, and the remaining portions of these ampullae become the seminal vesicles (*vs*). This is very clearly seen in fig. 15, F. The ejaculatory duct arises as a median invagination from the bases of the imaginal discs among the various forms.

In *Polemon*, *Pteromalus* and *Vespa* the penis valves fuse for the greater part of their length. This results in converting the enclosed space into a tube. This tube is in continuation of the ejaculatory duct, as illustrated by fig. 18, E. In *Apis* the apical portion of the penial tube, which is of less diameter than the basal portion, forms the ejaculatory duct. The ends of the vasa deferentia may open directly into the anterior limit of the ejaculatory duct as is seen in *Polemon*, *Pteromalus*, *Vespa* and *Prosopis*; or the anterior region of the ejaculatory duct may flatten and diverge into two short arms into each of which opens the vas deferens of its side as is seen in *Apis mellifica*.

In the sawflies *Cephus* and *Nematus* a tongue-shaped depression (*l*) which

starts from the dorsal side of the anterior limit of the ejaculatory duct divides it into two short ducts (*le*) (*vide* fig. 15, G, H) into each of which opens the vas deferens of its side.

From the above account of the efferent ducts it becomes evident that in the adult insect the vasa deferentia, accessory glands and the seminal vesicles are derived from the mesoderm. The ejaculatory duct and in some cases (as seen in *Cephus*, *Nematus* and *Apis*) the basal portions of the vasa deferentia are of ectodermal origin.

Three views have been advanced with regard to the nature of the efferent genital system of the male.

According to the first view, the entire efferent genital system is derived from the ectoderm. In the Hymenoptera, Michaelis is the only author who upholds this. He based his interpretations mainly on dissections and his observations, therefore, cannot be regarded as final and they have not received support from other investigations on Hymenoptera, or from other recent investigators working on other orders.

According to the second view, the posterior terminal portions of the vasa deferentia (*e.g.* paired ejaculatory ducts of Pruthi), the accessory glands and the ejaculatory duct are derived from the ectoderm. Only the anterior region of the vasa deferentia are of mesodermal origin.

Boulangé (1924), working with *Sirex*, is the only author who seems to uphold this view in the Hymenoptera, but he does not advance convincing proof. He is not even sure about the origin of the vasa deferentia. That the vasa deferentia are mesodermal in origin is so well known, that it is difficult to understand how Boulangé could have missed this point. The only argument that I can advance is that Boulangé based his interpretations on oblique sections, a fact which he admits in his account. Furthermore, it is very unfortunate that Boulangé makes no mention of the then recent work of Zander (1916), which might perhaps have simplified matters for him. Among recent authors working on orders other than Hymenoptera the following hold the above view: Pruthi (1924, 1924a) and Metcalfe (1932, 1932a) in Hemiptera and Coleoptera, Mehta (1933) in Lepidoptera and Muir (1918) in Coleoptera.

According to the third view, the ejaculatory duct alone is of ectodermal origin. The seminal vesicles, accessory glands, vasa deferentia and their terminal ampullae are of mesodermal origin, there being no counterparts of the paired or lateral ejaculatory ducts of Pruthi. This view has received wide acceptance and in the Hymenoptera embryological investigations by Carrière and Bürger on the mason bee *Chalicodoma* confirm it. Most authors are in complete agreement with this view. While my account is in general agreement, it may be pointed out here, as has been said above, that the basal portions of the vasa deferentia in *Cephus*, *Nematus* and *Apis* are derived from the ectoderm. Zander (1916) and Bishop (1920) working with *Apis* arrived at similar conclusions. The paired ejaculatory ducts of authors (Pruthi, Mehta and Metcalfe) seem to correspond to these basal ectodermal portions.

In my opinion the most reasonable thing would be to demarcate the mesodermal regions of the vasa deferentia, which end at their terminal ampullae, as shown by the embryological researches of Wheeler (1893), Carrière and Bürger (1897) and Roonwal (1937) and the post-embryonic researches of most recent authors.

The ejaculatory duct has been admitted as of ectodermal origin. In some cases its apical end becomes divided into two short lateral ducts as seen in *Cephus*, *Nematus* and *Apis*, and also shown to occur by previous authors, viz.

Metcalfe and Pruthi. It appears that this section of the ejaculatory duct which joins the mesodermal vasa deferentia is not present in the forms on which advocates of the third view have worked and this has apparently led them to criticise others.

Accessory glands.

Two types of such structures are known to exist among insects—ectadenia and mesadenia. In the Hymenoptera, as seen from the present study, only mesadenia exist. In other forms, as shown by Pruthi in Coleoptera and Rawat in Hemiptera, both ectadenia and mesadenia are present. In still other forms, as those described in Lepidoptera by Mehta, and in Coleoptera by Metcalfe and Muir, only ectadenia exist, for these authors clearly state that they arise from the ectoderm. When mesadenia are present they seem to be always derived from the end section of the vasa deferentia. This fact is admitted by most recent authors and is also shown by my investigations.

Seminal vesicles.

These structures with few exceptions (Metcalfe in Coleoptera, Boulangé in *Sirex* (Hymenoptera), etc.) are considered to be derived from the mesoderm, and from the present study it becomes evident that this is so.

Summary.

The rudiments of the genitalia arise as a pair of buds from the hind margin of the ninth sternum. The claspers are regarded as homologous to the parameres of other orders, *e.g.* Coleoptera, Diptera, etc., the inner claspers being mere outgrowths on the outer. In *Cephus*, *Nematus*, *Polemon*, *Pteromalus*, *Vespula* and *Apis* the penis gives rise to a pair of anteriorly directed processes (the sagittae of authors) which are considered to be modifications of the penis. The structures described in *Prosopis* as the " ventral depression of the penis valves " are also modifications of the penis and are not comparable with the parameres. Pruthi and Metcalfe have shown that the styli of such insects as the Orthoptera and Ephemeroptera are represented in the ontogeny of Hemiptera and Coleoptera. It appears that in *Polemon* and *Pteromalus* such structures are represented in ontogeny by a pair of buds on the ninth sternum which atrophy in course of development. The vasa deferentia, accessory glands and seminal vesicles are of mesodermal, the ejaculatory duct of ectodermal origin. In *Cephus*, *Nematus* and *Apis* the apical end of the ejaculatory duct becomes divided into two short ducts into which joins the vasa deferentia. In *Pteromalus* a short conical median diverticulum develops from the ejaculatory duct. This structure probably stores sperm for a single complete discharge. My observations on *Polemon*, *Pteromalus*, and *Prosopis* show that in these insects a polypod stage occurs in development.

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ABBREVIATIONS ON THE FIGURES.

ad	anterior process of the penis.
ag	accessory gland.
ag′	female accessory gland.
al	alkaline gland.
av	anterior valve.
b	basal ring.
b7	buds of 7th segment.
c	rudiment of claspers.
co	common oviduct.
coi	invagination of common oviduct.
d	anterior median diverticulum of the ejaculatory duct.
dp	dorsal plates of the penis.
e	ejaculatory duct.
f	follicle.
fp	subgenital plate (7th sternum).
g	female accessory pouch.
gc	genital chamber.
gcr	rudiment of the genital chamber.
gu	gut.
h	hypandrium.
i	invagination.
ic	inner claspers.
id	buds of the genitalia.
ip	inner plate.
la	lateral arm of common oviduct.
lv	lateral valve.
m	muscle.
n	nerve ganglion.
o	oviduct.
oc	outer clasper.
op	outer plate.
ov	ovary.
p	penis.
pd	poison duct.
pg	acid gland.
pgr	rudiment of acid gland.
ps	poison sac.
pt	penial tube.
pv	posterior valve.
pvp	process of posterior valve.
sh	sheath.
sp	spermatheca.
spr	rudiment of spermatheca.
st	stylet.
t	testis.
ta	terminal ampulla of oviduct.
te	terebra.
v	vagina.
vd	vasa deferentia.
vd′	ventral depression.
ve	vestibulum
vs	seminal vesicle.
x	region of ectoderm separating the common oviduct and the spermatheca.

THE AQUATIC HEMIPTERA OF THE HEBRIDES

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Manuscript received 14.viii.1941.

Read 1.iv.1942.

With 26 Text-figures.

This paper is based on the study of 1050 specimens of aquatic Hemiptera collected on the Hebridean islands by Prof. J. W. Heslop Harrison, D.Sc., F.R.S., and members of his biological parties, between 1935 and 1939. It also summarises previous records from this area and attempts to compare the fauna with that of the rest of the British Isles.

I have examined all the specimens mentioned above, and microscopical preparations have been made from 115 of them. Many have also been examined by Prof. Heslop Harrison, and others from the islands of Raasay

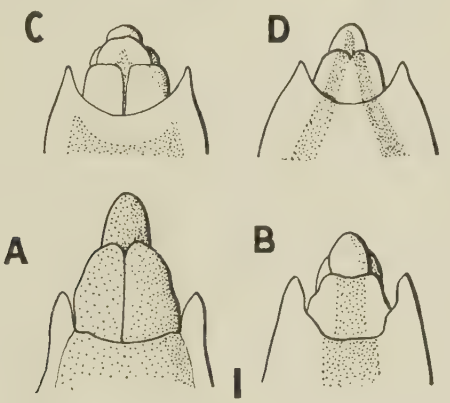
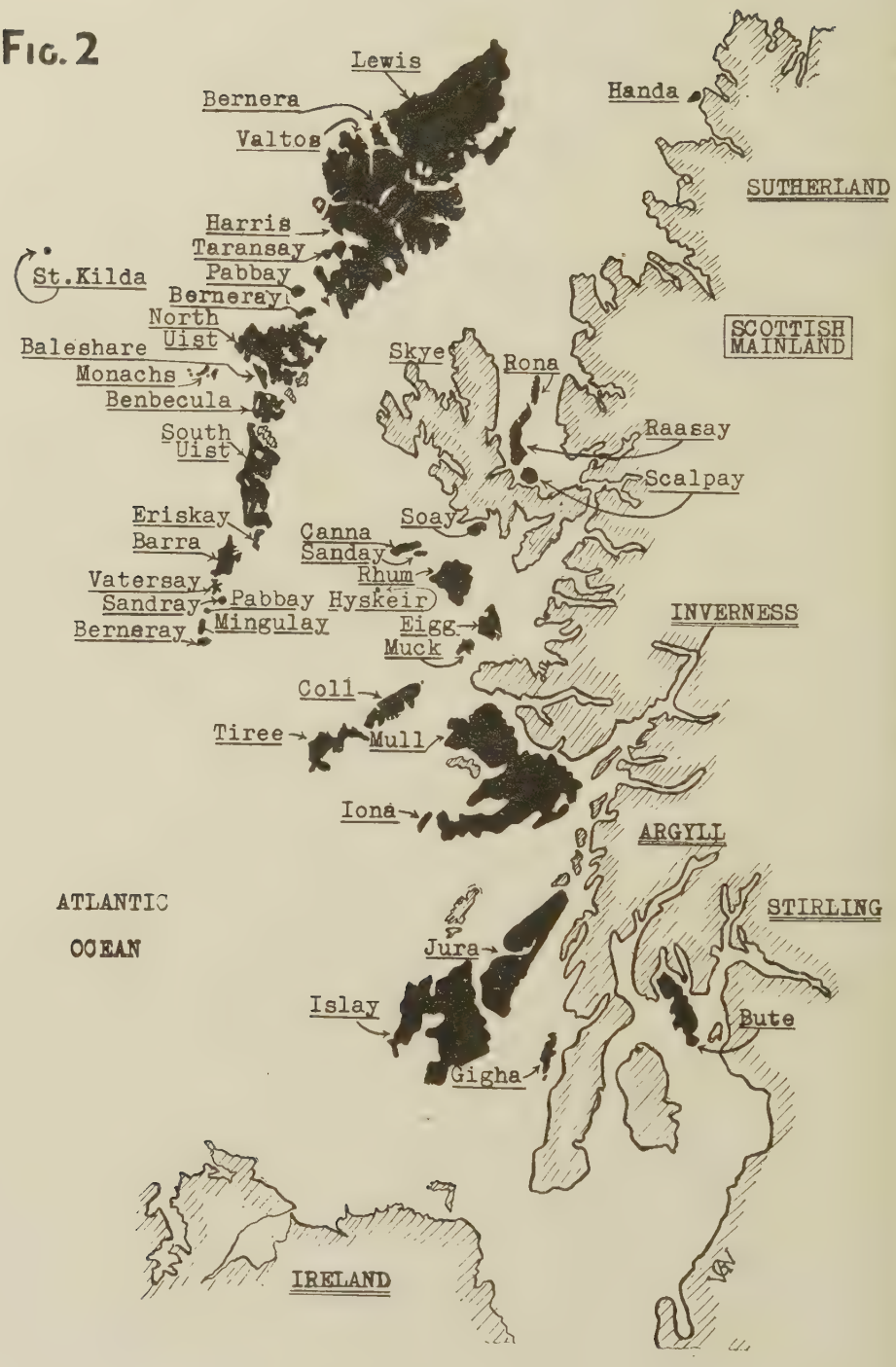


Fig. 1.—*a*, *b*, apex of the abdomen in *Gerris costai* (female) from Lewis; *c* and *d*, the same of *G. thoracica*. *a* and *c*, ventral view; *b* and *d*, dorsal view.

and Mull were identified by Dr. K. Jordan of Bautzen. The collections were made on 25 islands: those in the Inner Hebridean group were Tiree, Coll, Muck, Eigg, Rum, Hyskeir, Soay, Raasay and Handa, a small island off the west coast of Sutherland; those in the Outer Hebridean group were Berneray, Mingulay, Pabbay (south of Barra), Sandray, Vatersay, Barra, Eriskay, South Uist, Baleshare, The Monachs, North Uist, Berneray and Pabbay (in the Sound of Harris), Harris and Taransay. Collections were also obtained from Valtos in Lewis and from Bernera. Southern islands are listed before the northern ones.

It is worth mentioning that although the collections were made by eighteen different persons whose main interests, however, were botanical, not entomological, they are not large for such an extensive area. Therefore, as will be seen in the discussion at the end of this paper, common species appear to be more abundant than they are in fact. The reverse is true for the rarer species. Nevertheless the collections are unique, and, taken in conjunction with previous

FIG. 2


Lewis
Bernera
Valtos
Handa
SUTHERLAND
Harris
Taransay
St.Kilda
Pabbay
Berneray
North Uist
Baleshare
Monachs
Benbecula
South Uist
SCOTTISH MAINLAND
Skye
Rona
Raasay
Scalpay
Eriskay
Barra
Vatersay
Sandray
Berneray
Pabbay
Mingulay
Canna
Sanday
Soay
Rhum
Hyskeir
Eigg
Muck
INVERNESS
Coll
Tiree
Mull
Iona
ARGYLL
ATLANTIC OCEAN
STIRLING
Jura
Islay
Bute
Gigha
IRELAND

records, permit the construction of a true picture of the aquatic Hemipterous fauna of these islands. Later it is hoped that a short paper on the ecology will follow.

The present times being unfavourable to scientific work of this nature, it has not been possible to give details and measurements for every specimen, although such data would enable the present material to be compared more accurately with material from the mainland of Scotland, when obtained. However, I have selected suitable specimens and series and give measurements of body length, the proportions of the tibia, tarsus and claws of the middle leg of many of the CORIXIDAE (measured in 0·04 mm.), the number of pronotal lines, pegs on the male palae and number of combs in the strigils of the males in the CORIXIDAE, as well as a brief description of the general appearance, male abdominal segments and genitalia. Wherever previous works and records are mentioned these are accompanied by a number referring to the bibliography at the end of the paper. The nomenclature of the CORIXIDAE follows the latest work dealing with this group: "A Revision of the CORIXIDAE of India and Adjacent Regions," 1940, *Trans. Conn. Acad. Arts Sci.* **33**: 339–476, by Prof. G. E. Hutchinson.

Records from Mull (7), Bute (7), Iona (1), Gigha (7), Islay (7), Jura (7), Canna (10), Sanday (10), Scalpay (4), Rona (4) and Benbecula (27), islands from which collections have previously been made, are indicated in the following detailed study only by numerical reference to the bibliography, but I have seen some of the specimens and made microscopical preparations of a few from Islay (17) and Jura.

Since 35 islands in all are mentioned, and as they are difficult to locate on most maps, a map showing their positions is included for reference (fig. 2).

I. THE SPECIES.

VELIIDAE.

Velia currens Fabricius.

Few specimens were taken by the Heslop Harrison expeditions: they were one larva from Muck, two females from Rhum, one male from Soay; in the Inner Hebrides. From the Outer Hebrides there were five females from Harris, one female from North Uist and one larva from Berneray. The specimens are all apterous and of a robust build, averaging 7 mm. in length. Thus they are on the large and dark side of the normal appearance, since the dark line at the sides of the abdomen is continuous and not interrupted as is usual. Nymphs were common in June and July. This species has been previously recorded from Islay (7), Jura (7), Canna (10), Raasay (4), Rona (4), Benbecula (27), Scalpay (4), Barra (5), S. Uist (6), St. Kilda (8) and Harris (2), but no macropterous examples are mentioned. It is therefore common in the Hebridean Islands, and the records indicate that, unlike the south, it is found on all types of habitat including ditches, pools and lakes.

GERRIDAE.

Gerris lateralis Schummel (Fieber *nec* Schummel).

One macropterous female of this rare species was discovered in the collections from Coll made in May 1937 by Dr. George Heslop Harrison. This is the only record for the Scottish Islands.

Gerris thoracica Schummel.

One macropterous female was collected at Valtos, on the west coast of Lewis in July 1939. This is a typical specimen measuring 11 mm. in length and 3 mm. across the middle coxae; it is therefore the narrow olivaceous form found in the greater part of the British Isles, unlike the broad russet-coloured form found in some parts of Ireland. The tip of the abdomen is shown in fig. 1, *c* and *d*. This species has previously been recorded from the islands of Raasay (4), Scalpay (4), Barra (5), and Benbecula (27).

Gerris costai Herrich-Schaeffer (emend.).

There are 24 specimens of this species in the collections, and all are of the typical robust type, russet brown in colour, with reddish thoracic discs. They came from the following islands :—

Inner Hebrides :—Coll : May 1937, 2 males each 11·5 mm. long and 3 females 11·5–12·5 mm. long.

Outer Hebrides :—Mingulay : July 1937, 2 males; Vatersay : July 1937, 1 male; North Uist : July 1938, 5 males, two 12 mm. long and three 13 mm. long; 3 females, one 12 mm. long and two 13 mm. long; Harris : July 1938, 3 males of average length 12·16 mm., and average breadth across the middle coxae of 3 mm., and 4 females of average length 12·9 mm. and average breadth across the middle coxae of 3·5 mm.; Lewis (Valtos) : July 1939, 1 female 13 mm. long and 3·5 mm. across the middle coxae. The genital segments are shown in fig. 1, *a* and *b*, for comparison with the female *G. thoracica*.

This species has previously been recorded from Islay (7), Jura (7), Benbecula (27), Mull (7), Canna (10), Raasay (4), Scalpay (4), Barra (5) and Harris (2); it is therefore common and widely distributed. It occurs in a wide variety of habitats including brackish pools.

Gerris lacustris L.

An uncommon Hebridean species recorded so far only from the southern half of the Inner Hebrides.

Eigg : July 1937, 1 brachypterous male 8·5 mm. long and one macropterous female 9·5 mm. long; Rhum : August 1937, 2 macropterous females each 9 mm. long; Soay : August 1937, 1 macropterous female 9 mm. long. Previously recorded from Islay (7) and Jura (7).

Gerris odontogaster Zetterstedt.

No specimens were found in the present collections, but it has previously been recorded from the islands of Mull (7), Raasay (4), Rona (4), Scalpay (4) and S. Uist (6).

Gerris spp. nymphs.

Barra : August 1939, probably fifth instar *G. costai*; Berneray : July 1939, probably *G. lacustris*.

Cimicidae.

Cryptostemma alienum Herrich-Schaeffer.

This species has been recorded from Jura by Hutchinson (7).

SALDIDAE.

Salda littoralis L.

Barra : August 1939, one typical female.

Previously recorded from Jura (7), Canna (10), Rona (4), Barra (5) and South Uist (6).

Saldula saltatoria L.

Previously recorded from Raasay (4), Barra (5) and Harris (2).

Saldula pallipes Fabricius.

Previously recorded from Sanday (10), Raasay (4), Jura (7) and Canna (10).

Saldula scotica Curtis.

Previously recorded from Jura (7) and Raasay (4).

Salda morio Zetterstedt.

Previously recorded from Barra (5) and Raasay (4).

NEPIDAE.

Nepa cinerea L.

One fifth-instar nymph from Muck, July 1939. Previously recorded from Islay (7), Canna (10) and Barra (5).

NOTONECTIDAE.

Notonecta glauca glauca L.

Soay : August 1937, one typical female 14 mm. long, and 3 fifth-instar nymphs probably belonging to this species. Previously recorded only from Islay (7), Raasay (4), Rona (4) and Barra (5).

Notonecta obliqua obliqua Gallén.

Inner Hebrides :—Tiree : July 1935, two females 15 mm. long; Coll : May 1937, 3 males and 1 female, all 15·5 mm. long; Muck : July 1939, 1 male 15 mm. long, 1 male 16 mm. long and 3 females all 16 mm. long; Eigg : July 1937, 2 specimens 16 mm. long; Rhum : May 1938, 1 male, August 1938, 8 specimens; Soay : August 1937, 4 males and 1 female, all 15 mm. long; Raasay : August 1937, 3 specimens.

Outer Hebrides :—Mingulay : July 1937, 1 male and 1 female; Barra : August 1939, 2 females 16 mm. long; Eriskay : August 1938, 1 female; South Uist : August 1938, 1 female; North Uist : July 1938, 2 males 15·5 mm. long; Harris : July 1938, 2 males; Berneray : July 1939, 1 male.

N. obliqua has previously been recorded from Islay (7), Benbecula (27), Rona (4), Scalpay (4) and Barra (5). This makes 17 islands, or half those on which collections have been made. All these 40 specimens are typical in appearance.

Notonecta nymphs were present in many of the collections and probably the majority are the larvae of *N. obliqua*. These came from Eigg May 1938, Rhum May 1938, Raasay August 1937, Barra August 1939, Sandray July 1939, Vatersay July 1939, Berneray July 1939, one being 15½ mm. long,

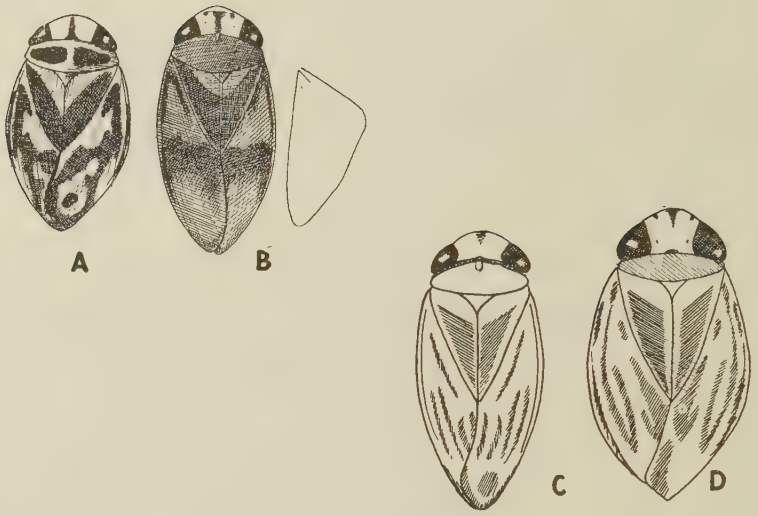


Fig. 3.—*a*, *Micronecta poweri* from South Uist (brachypterous male); *b*, *M. poweri*? (submacropterous female) from Eriskay, showing size of wing drawn to same scale; *c*, *M. minutissima* from Eriskay (macropterous female); *d*, *M. scholtzii* from Gloucestershire (brachypterous female).

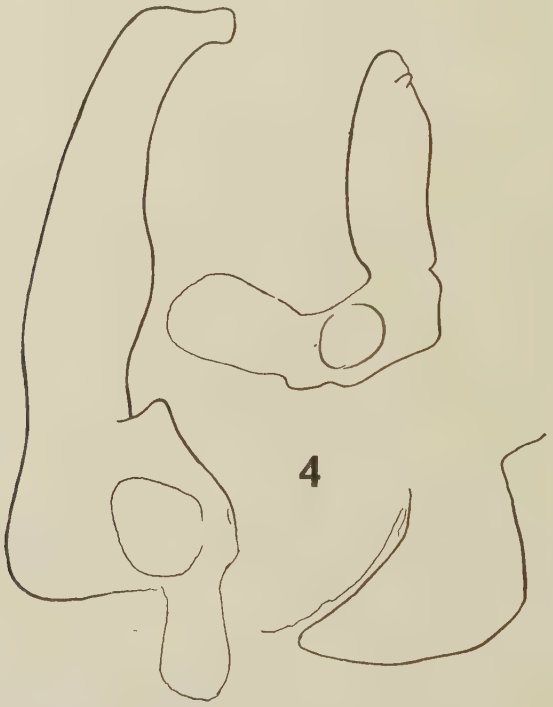


Fig. 4.—Parameres and lobe of the 5th male tergite in *Micronecta poweri* from South Uist.

Pabbay (Harris) July 1939, Lewis (Valtos) July 1939, Taransay July 1938. Nymphs have previously been recorded from Jura (7), Canna (10) and South Uist (6).

Notonecta obliqua obliqua var. *delcourti* Poisson.

One female of this striking variety was collected on Muck in July 1939. This specimen is 16 mm. long. and shows the large pale brown blotch on the middle of the corium characteristic of this variety first described from France. I have taken it occasionally in Cornwall, Somerset, Hants and Gloucestershire.

CORIXIDAE.

Ninety-eight Corixid larvae were found in collections dating from May to August. Few of these can be identified with certainty, except those of the genera *Micronecta*, *Cymatia*, *Glaenocorixa* and *Corixa* in all stages, and those of *Corixa punctata*, *C. dentipes*, *C. scotti*, *C. striata* in the last instar, and, when the ecology is known, those of the subgenera *Anticorixa*, *Callicorixa* and *Halicorixa*.

Micronecta poweri Douglas & Scott.

One brachypterous male collected on South Uist in August 1938 is a typical specimen. The strigil and palae are quite typical as are the lobes of the sixth tergite and left valve of the eighth tergite, and genitalia. The relative lengths of the middle legs are : tibia 11, tarsus 15, claw 10 (these figures for

FIG. 5.—Claw and tarsus of the middle leg of *Micronecta minutissima* from Eriskay.

the *Micronecta* specimens are merely arbitrary and not in twenty-fifths of a millimetre) (fig. 3, a and 4).

Two submacropterous females, possibly of this species, collected on Eriskay in August 1938 are rather pale in colour. The pronotum is not as long as in fully macropterous examples (fig. 8 B, 4), neither are the membranous wings quite so long, nor the membrane of the hemielytra so fully developed. Apart from this, the markings are barely consistent with *M. poweri* and the proportions of the segments of the middle leg are : claw 10, tarsus 15, tibia 8·4. The claw tarsus ratio is correct, but the tibia is short. It is to be regretted that no males were taken. These specimens are illustrated (fig. 3, *b*), since they are not quite like any *M. poweri* studied when I wrote my paper on the British species of *Micronecta* (17).

Micronecta minutissima L.

A single female was collected on Eriskay in August 1938. I refer it to this species although no male was taken, since in appearance it resembles the three other definitely British specimens from Colchester which I have before me for comparison. Like these three, it is macropterous, and the pronotum is far shorter than in macropterous females of *M. poweri* (fig. 8 B, 4); moreover the claw tarsus ratio is 10, 18, agreeing quite favourably with the other British specimens which are 10, 17; this ratio in *M. poweri* is 10, 14–10, 15. Two other specimens of *M. minutissima* in the collection of the late Canon

Fowler, without definite locality but presumably British, also agree with this Hebridean example. The most peculiar thing about this specimen is that the left middle tarsus is definitely two-segmented (fig. 5). This two-segmented tarsus is met with in only the very primitive notogean Corixid genus *Diaprepocoris*, apart from which I know of no specimen throughout the Corixidae which shows this condition; it is unique. This specimen is illustrated in fig. 3, *c*.

Cymatia coleoptrata Fabricius.

Two males and one female of this species were found in the collections from the island of Tiree in the Inner Hebrides, July 1935. There is a previous Hebridean record for Harris by Dale, quoted by Saunders, but it is not mentioned by Dale in his paper on the Hemiptera of Harris, 1882, nor are there any such specimens in his collection studied by the late Commander J. J. Walker in 1933. Apart from these specimens, *Cymatia coleoptrata* does not appear to occur north of a line drawn across from the Wash to Hereford and down to the Severn Estuary, and is common only in a broad strip along the coastlands of the southern counties, nor does it occur in Ireland and, further, does not appear to have been collected in Cornwall. The vast majority of these southern specimens are brachypterous and incapable of flight. The only macropterous specimens on record were collected by myself, four from Hereford, two from Wiltshire and one from Somerset, while one specimen is recorded from Poland by Jaczewski, so that the chances of dispersal are naturally small (fig. 8 B, 3). There is therefore a distributional gap of 350 miles of land and 10 of sea between the locality of the specimens taken in Tiree and their relatives in the south.

On examination these three specimens are very like the southern form; what slight variations occur could almost be explained as being comparable with the degree of variation found in other Hebridean material yet to be discussed, but the lesser paramere of one male is very different from that seen in the southern form that corresponds closely with the continental type. The lesser paramere of the second male is also different, but this tiny object was lost in the process of dehydration and cannot be figured here. That variations of a marked degree can be found in this organ among specimens of Corixidae from the same locality is demonstrated later in this paper, but they are exceedingly rare and may be disregarded here. I suggest that these definite structural variations from the typical form, the flightless condition of the insect and its isolation warrant the creation of a subspecies and propose the following name :—

Cymatia coleoptrata insularis subsp. n.

Like *Cymatia c. coleoptrata* Fabricius in general appearance and structure, and brachypterous and flightless, but having lesser male parameres of a different shape, and isolated in the Hebridean Islands. Structure as fig. 8 A. The relative lengths of the segments of the middle leg are : claw 12, tarsus 19, tibia 22, femur 40 in the female and for the male, claw 11, tarsus 17, tibia 20, femur 37 (figs. 6, 7 and 8 A).

Cymatia bonsdorffi Sahlberg.

Inner Hebrides :—Tiree : September 1935, 6 brachypterous males and 3 brachypterous females. The markings are normal and the males measure 5–6 mm. in length. Hemielytra are slightly shorter than normal. Male abdominal segments and parameres as figs. 9, and 10, *c*, *d*, *e*, *g*. The lengths

of the middle leg segments are: claw 17, tarsus 30, tibia 39. July 1935, 1 macropterous male 6 mm. long, 1 male and 1 female brachypterous. The macropterous specimens have a longer and more convex pronotum and the thorax is thicker dorso-ventrally. The hemielytra are also longer and the membrane more fully formed, the wings being as long as the abdomen (fig. 8 B, 1, 2); Coll: July 1935, 2 brachypterous males; Muck: May 1935, 2 brachypterous males; 1937, 6 brachypterous males and 3 brachypterous females.

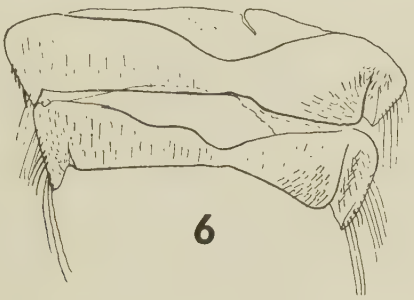


Fig. 6.—Sixth and seventh male abdominal segments of *Cymatia coleoptrata insularis.*

These males measure 5·5–6 mm. in length and are normal in colour and markings. The wings are of variable length, in some they reach down to the posterior border of the metanotum, in others to the end of the embolium. The lengths of the middle leg segments in four specimens were: claw 18, 19, 20, 20; tarsus 31, 31, 31, 31; tibia 36, 36, 40, 38; Eigg: August 1936, 1 brachypterous male; Rhum: July 1937, 1 macropterous male still teneral, and one fifth-instar nymph; August 1938, 4 brachypterous males and 3

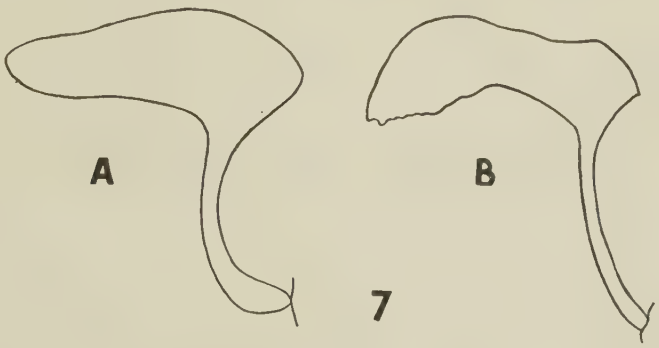


Fig. 7.—Lesser paramere of *a*, *Cymatia coleoptrata coleoptrata*; *b*, lesser paramere of *C. c. insularis.*

brachypterous females; Hyskeir: August 1938, 1 brachypterous male; Soay: August 1937, 2 males, one macropterous and the other brachypterous.

Outer Hebrides:—Mingulay: July 1937, 2 brachypterous males; Barra: September 1935, 5 brachypterous males 6 mm. long and 6 brachypterous females 6·5 mm. long, 1 macropterous female 6·5 mm. long. The wings are short in the brachypterous series and the hemielytra are slightly longer than usual but the colour and markings are normal. The lengths of the segments of the

middle leg of one male were : claw 19, tarsus 33, tibia 39. The shapes of the male parameres and the brachypterous and macropterous types of pronotum in the female are shown in figs. 10, *a–g*, and 8 B 1 & 2 respectively.

Thus four out of a total of 51 specimens were macropterous, a very high proportion for this species. It has previously been recorded from Gigha, Islay, Jura (7), Mull (7), Scalpay (4), Harris (2) and Barra (5), and thus occurs on four times as many Inner as Outer Hebridean islands.

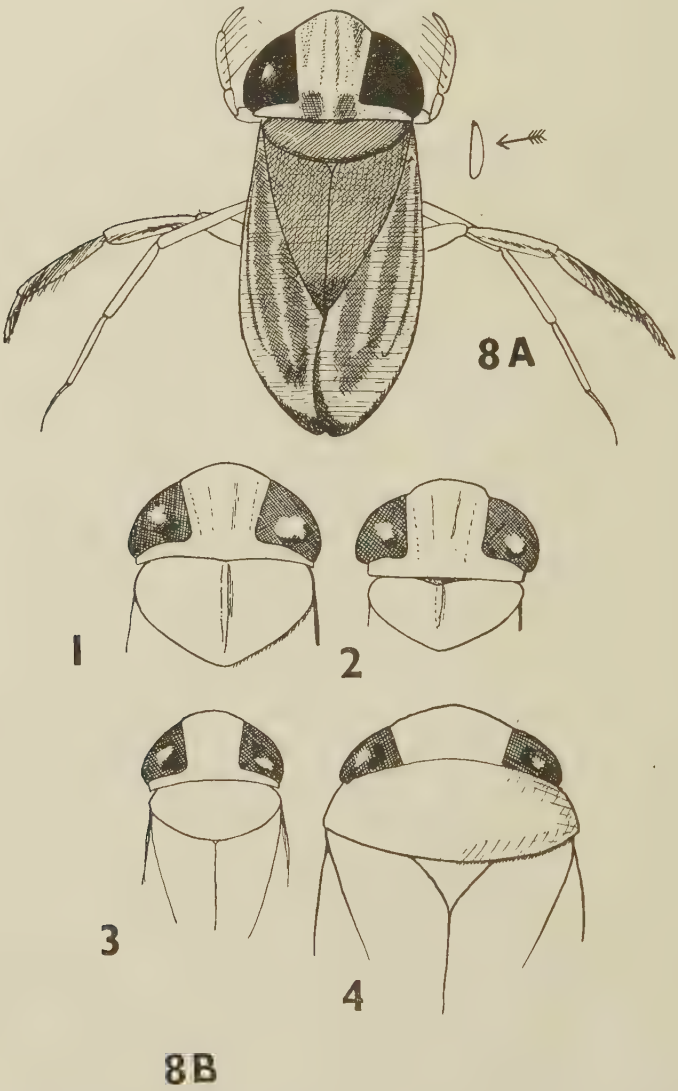


Fig. 8.—A, male of *Cymatia coleoptrata insularis*. Arrow indicates size of wing drawn to same scale. B, 1, head and pronotum of macropterous female *Cy. bonsdorffi* ; 2, head and pronotum of brachypterous female *Cy. bonsdorffi* ; 3, head and pronotum of macropterous female *Cy. coleoptrata* ; 4, head and pronotum of macropterous female *Micronecta poweri* ; compare with fig. 3, *a* and *b*.

Glaenocorixa cavifrons Thomson.

This interesting species is difficult to capture because of its habit of roving about in deep open water, especially in sandy bays of pools and tarns. No specimens were found in the present collections, but it has previously been collected on Islay (7), where it is represented by a large very dark form, and

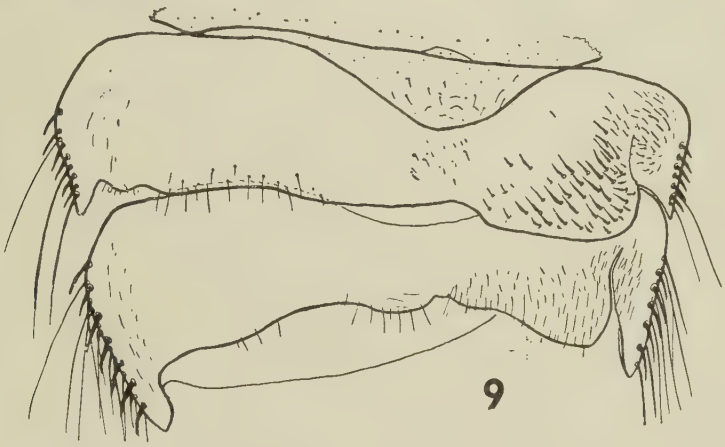


Fig. 9.—Sixth and seventh male abdominal segments of *Cymatia bonsdorffi* from Tiree.

from Jura, where the specimens are intermediate between the typical dark Scottish form and the smaller pale Southern specimens; I have the specimens from these islands before me. It has also been taken on Barra, one nymph from a peat cutting near Loch Obe, and 3 adults and nymphs from Lochan nam Faoileann South (5).

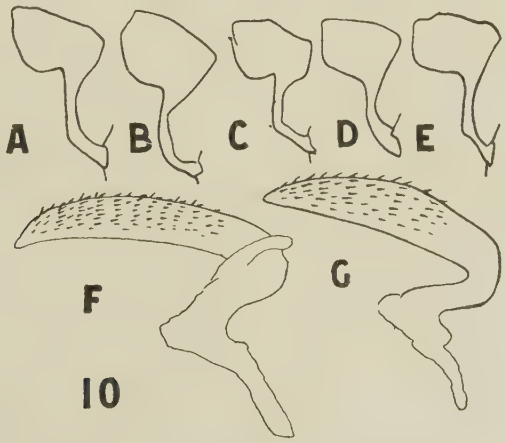


Fig. 10.—Parameres of *Cymatia bonsdorffi*.

Corixa (*Callicorixa*) *wollastoni wollastoni* Douglas & Scott.

This species was originally described in 1865 by Douglas and Scott from two specimens captured by T. V. Wollaston at Hebden Bridge near Halifax, Yorkshire, and the original specimens were examined by Fieber. Unlike

subsequent species belonging to the subgenus *Callicorixa* described by them, *C. wollastoni* has proved to be a true and very distinct species found in the British Isles in peaty pools in the mountainous parts of Ireland, N. Wales, in the Pennine Chain and the Lake District. In all these places it occurs only at an altitude about 1500 ft. or over. In Scotland the few available records indicate that there it occurs down to sea-level. The present collections contain 42 specimens all of which came from the Outer Hebrides.

South Uist: August 1938, 3 males and 3 females. These are on the small size, being 6·5 mm. long, whereas some females I have seen reach 8 mm. This series is very dark in colour, making it difficult to count the pale pronotal lines, which appear to vary from 9 to 10.

Baleshare: April 1938, 3 males and 6 females. A typical series with pronotal lines varying from 8 to 11.

North Uist: July 1938, 3 males and 9 females. These males are 6·5 mm. long, typically dark in appearance and with mildly infuscated heads and legs. The paler pronotal lines number 9, 9 and 10. The lengths of the segments of the middle legs are: claw 23, tarsus 24, tibia 34. Including the insertions where pegs have been knocked off the palae the pegs vary as follows: basal row 17 on one pala; 19 on the others; apical row 11 in two, 13 in two, 12 in two. Seventh male abdominal segment as fig. 26, *b*.

Harris: July 1938, 3 males and 12 females. The females vary in length from 7 to 7·8 mm. and all have 10 paler pronotal lines. The males vary in length from 6·25 to 6·5 mm. The pegs in the basal row of the right palae are 18, 19, 20; in the apical row 11, 12, 12. On the left palae the basal rows have 16, 20, 20 and the apical row 11, 12, 12. The lengths of the segments of the middle leg vary from claw 23, tarsus 25, tibia 33 to claw 24·5, tarsus 25, tibia 35. Fig. 26 shows the pronotum (*i*), abdominal segments (*a* and *b*), and parameres (*e*), and the shape of the black spot on the posterior tarsi is as in fig. 12, *e*.

The species also occurs in the Inner Hebrides. Prof. Heslop Harrison says it is not common in the smaller peaty pools on Raasay and Scalpay, the specimens being identified by Dr. K. Jordan; and Hutchinson says of Islay and Jura: "a number of obscurely marked var. *wollastoni* give the series (of *C. praeusta*) a darker appearance than is usual." Whether these are to be regarded as true *C. wollastoni* or atypical *C. praeusta* is not clear. Prof. Heslop Harrison also took it in Loch na Liana Moire on Benbecula in 1940 (27).

Corixa (*Callicorixa*) *wollastoni caledonica* Kirkaldy.

In 1870 Douglas and Scott described a new species from Loch Leven and called it *Corixa cognata*; this was renamed *Corixa caledonica* in 1897 by Kirkaldy. I have seen the original specimens and possess a similar series collected in Loch Leven by the Rev. E. J. Pearce, M.A. These specimens are in appearance very different from *Corixa wollastoni*. They are dumpy in comparison, and both males and females measure 6 mm. in length. The ground-colour of the pronotum and hemielytra is a clear yellow instead of brown and the black markings are finer and stand out clearly; those on the corium form an open disordered disjointed pattern unlike the scattered pale brown markings on a black background seen in *C. wollastoni*. To the naked eye all the legs look shorter and the infuscation, if present, is very slight. The palae also appear slightly smaller and less dilated apically, but the greatest differences

are seen in the male genitalia, where the parameres are smaller and intermediate between those of *C. praeusta* and *C. wollastoni*. On these characters, if constant in other Scottish material, one would be justified in regarding *C. caledonica* as a good species. However, a series in the present collections containing 5 females, but unfortunately only a single male, are somewhat intermediate between the form found in Loch Leven and the typical *C. wollastoni*. These specimens were collected on the island of Handa on the 31st August 1937. They are a little longer, measuring 6–6·5 mm., and are a little darker than the Loch Leven series, so that although the hemielytral markings are similarly disjointed, they appear as pale yellowish vermiculations on a black background; and the legs do not appear so short to the naked eye. On microscopical examination the genitalia are consistent with the Loch Leven material and the front legs and palae of the single male are very similar, but otherwise the differences are too much within the limits of variation for discrimination from *C. wollastoni*. In the circumstances I provisionally regard those specimens showing the combination of dumpy build, open corial pattern and different genitalia as a subspecies of *Corixa wollastoni*, but this cannot be regarded as final until further material is available from the mainland of Scotland for comparison. With this in view, I am giving the following measurements and the drawings shown in fig. 26, *c*, *f*, *k*. The Loch Leven specimens have 7–10 pale pronotal lines, the pala pegs are 17–19 in the basal row and 12 in the apical row. The lengths of the segments of the middle legs are : claw 19, tarsus 23, tibia 30. The other structures are shown in fig. 12, *a*, *b*, *c*.

The specimens from Handa have 8–10 pale pronotal lines. The male has 17 and 18 pegs in the basal row of pala pegs and 12 and 13 in the apical row. The lengths of the segments of middle legs are : claw 23, tarsus 24, tibia 33. For typical *C. wollastoni* the lengths of the segments of the middle leg average : claw 23·5, tarsus 24·6, tibia 34.

Corixa (*Callicorixa*) *praeusta* Fieber.

Inner Hebrides :—Tiree : September 1935, 1 male and 5 females. July 1935, 3 males and 1 female; Coll : July 1937, 1 male and 1 female; Muck : May 1935, 1 female; 1937, 4 males and 2 females; Eigg : August 1936, 1 male and 4 females; July 1937, 2 males and 4 females; July 1937, 5 males and 3 females. One of these females is still teneral and another has only 7 pale pronotal lines. These males are fully described to illustrate variation and for comparison with the *C. wollastoni*. Colour and markings quite typical. One has 9 pale pronotal lines and the others 10. Length 6–6·5 mm. Pala pegs vary from 17 to 19 in the basal row and 8 in the distal row. The lengths of the segments of the middle legs are for three specimens : claw 23, 24, 24, tarsus 25 throughout, tibia 34, 34, 35. Drawings of the abdominal segments are given in fig. 11, *b* and *d*, and the paramere of one male in fig. 26, *h*. Rhum : July 1937, 4 males and 1 female. These males are not quite typical; they are darker than usual, the legs and head being diffusely infuscated; moreover the markings on the corium are fragmentary and not unlike those found in *C. wollastoni*. The dark hemielytral markings predominate but the pale intervals are clear and pale yellowish-brown. The pale pronotal lines are wider than the thin black ones and number 10, 9, 7, 7, with a suspicion of an eighth. A count of the pala pegs shows 16, 19, 19, 19, 20, 21 and 22 in the basal row and 8, 8, 8, 9, 9, 10, 10 in the apical row. The lengths of the segments of the

middle legs are : claw 23 in three specimens examined, tarsus 24, 24, 25 and tibia 34 in all. The parameres and pronotum, shape of the black spot on the posterior tarsi and variation in the abdominal segments are illustrated in fig. 26, *g*, *j*; fig. 12, *d*; and fig. 11, *a*, *c*, respectively.

C. praeusta has previously been recorded from Islay, Jura (7), Raasay (4), Scalpay (4) and Barra (5). The distribution in the Hebrides is thus a complete reversal of that found in *C. wollastoni*.

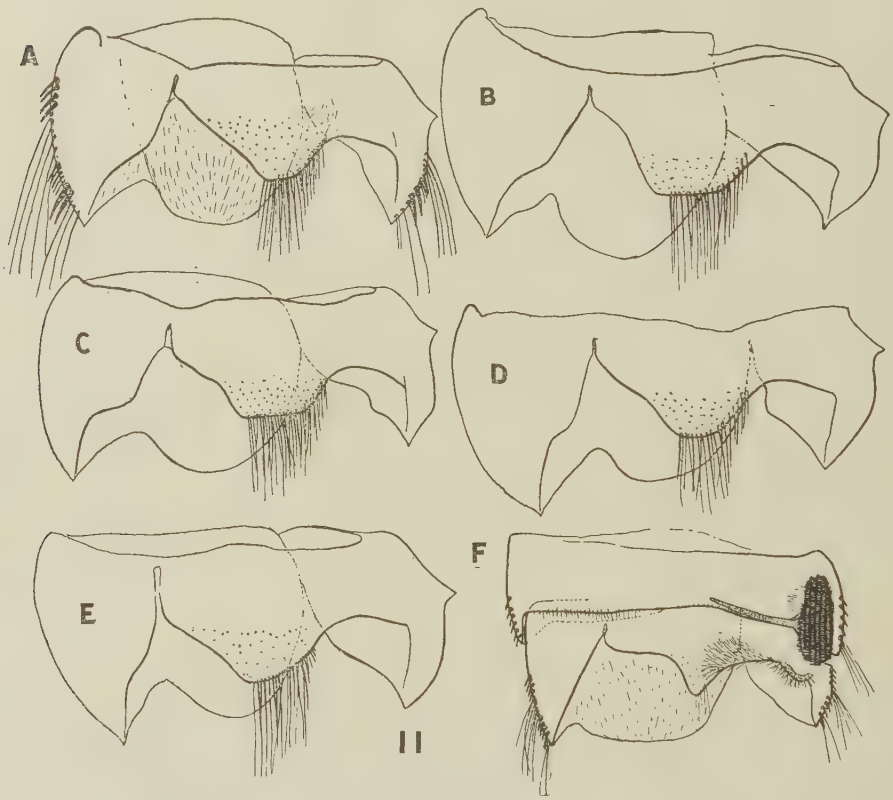


Fig. 11.—Seventh male abdominal segment in *C. praeusta* from *a*, Rhum; *b*, Eigg; *c*, Rhum; *d*, Eigg; *e*, Barra; *f*, sixth and seventh male abdominal segments in *C. striata* from Taransay.

Corixa (*Vermicorixa*) *lateralis* Leach.

One typical female was found among a long series of Corixidae taken in North Uist in July 1938. No other specimens were found in any other collections. The species was recorded from Gigha in the south of the Inner Hebrides by Hutchinson, who mentions a sparsity of material. This is the only other Hebridean record of a species which is among the commonest in the southern half of England and Wales, and widely distributed elsewhere.

Corixa (*Vermicorixa*) *nigrolineata* Fieber.

15 males and 28 females were found in the collections and 39 of these came from the Outer Hebrides. Most of the specimens are slightly darker than usual but apart from this the series is typical.

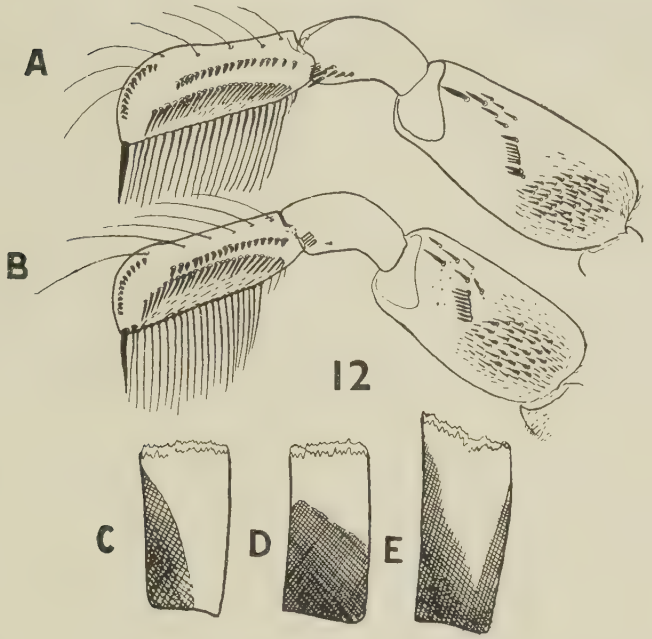


FIG. 12.—*a*, front leg of *Corixa* (*Callicorixa*) *w. caledonica* from Handa; *b*, front leg of *Corixa* (*Callicorixa*) *w. caledonica* from Loch Leven; *c*, black spot on apex of hind femora of *C.* (*Callicorixa*) *w. caledonica*; *d*, *C.* (*Callicorixa*) *praeusta*; *e*, *C.* (*Callicorixa*) *wollastoni* from Harris.

Inner Hebrides :—Hyskeir : August 1938, 1 female; Handa : August 1937, 1 male and 2 females.

Outer Hebrides :—Baleshare : April 1938, 5 males and 7 females, of which several have only 6 pale pronotal lines; North Uist : July 1938, 3 males and 5 females. One of these males is 6 mm. long and is darker than usual, but

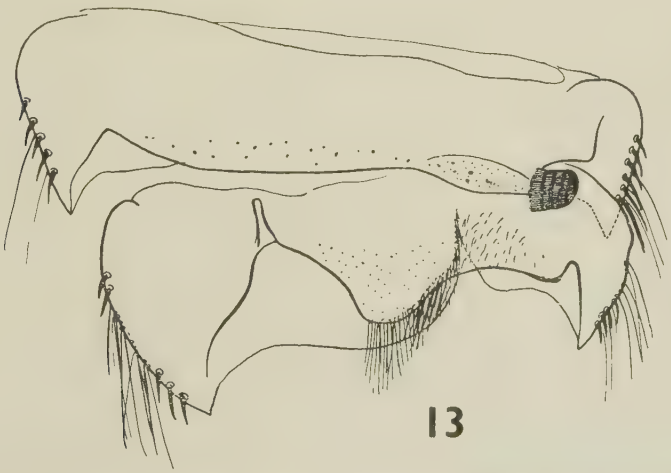


FIG. 13.—Sixth and seventh male abdominal segments of *Corixa nigrolineata* from North Uist.

this is due to an intensification of the pale ground-colour. The dark markings are very clear cut and a little thicker than the pale ones. There are 7 pale pronotal lines, legs and head mildly infuscated, 28 pegs on each pala, 6 combs in the strigil. The lengths of the segments of the middle leg are: claws 23, tarsi 22, tibiae 30. Genitalia typical. Abdominal segments as fig. 13. Pabbay (Harris): July 1936, 1 female; Harris: July 1938, 1 female; July 1938, 6 males and 10 females. These are dark specimens, so much so as to make it difficult to count the pronotal pale lines; in the females these appear to be 8–9. The males are 4·5–5 mm. long and the dark lines are two-thirds thicker than the pale ones. One specimen has 4 strigil combs only. Pale pronotal lines number 7, 7, 7, 7, 8, 8, and the pala pegs, taking the right pala first, number 27–28, 29–30, 25–23, 29–25, 25–28. Taransay: July 1938, 1 female.

Corixa nigrolineata has been previously recorded from Bute (7), Islay (7), Canna (10), Sanday (10), Raasay (4), Barra (5), S. Uist (6), Harris (3), Benbecula (27), and also from the Shetlands (7).

Corixa (*Retrocorixa*) *venusta* Douglas & Scott.

The collections contain 31 specimens of this species and they all come from the Outer Hebrides. Eighteen are males.

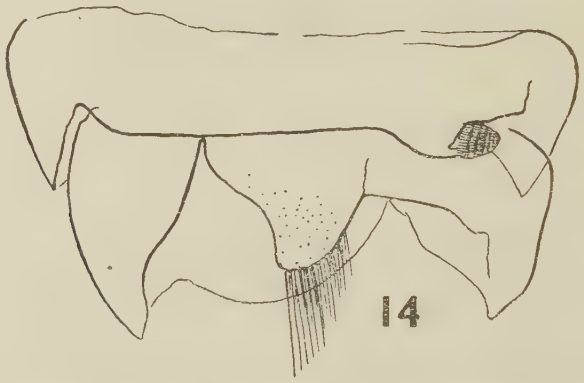


Fig. 14.—Male abdominal segments, 6th and 7th, of *Corixa venusta* from Harris. Chaetotaxy omitted.

Pabbay (Barra): July 1939, 1 male; Vatersay: July 1939, 1 female; South Uist: July 1938, 1 male; North Uist: July 1938, 6 males and 4 females, 4–4·5 mm. long, *i.e.* rather small; Pabbay (Harris): July 1939, 1 male and 1 female; Harris: July 1938, 7 males and 7 females. Quite a typical series, dark in colour with fragmentary but distinct markings, the dark ones predominating. The females are all 5 mm. long and all have 7 pale pronotal lines. The males are 4·5–5 mm. long and all have 7 pale pronotal lines. In one specimen there are 4 strigil combs, in one 5 combs and a little extra one, in another 5 combs, a fourth has 4 combs and a little extra one, and the remainder have 6 combs. Taking the right pala and the proximal row first in each case, the pala pegs number 20 6–20 5, 17 7–indistinct, 20 6–20 6, 18 5–18 5, 18 6–19 6, 20 6–20 6. The lengths of the segments of the middle leg vary as claws 25–26, tarsi 19–20, tibiae 26–27. For drawings of the male abdominal segments and lesser parameres see figs. 14, and 17, *f* respectively. Berneray: July 1939, 2 males.

Corixa venusta has previously been recorded from Bute (7), Gigha (7), Islay (7), Canna (10), Sanday (10), Raasay (4), Rona (4), Scalpay (4), and from the Orkneys (7).

Corixa (*Retrocorixa*) *semistriata* Fieber.

This species seems to be as uncommon in the Hebrides as elsewhere, but it appears to be quite widely distributed.

Inner Hebrides :—Tiree : September 1935, 1 male and 3 females; Muck : July 1939, 4 females; Handa : August 1937, 1 male.

Outer Hebrides :—Mingulay : July 1937, 1 male; Barra : August 1939, 4 males and 7 females. These are quite typical specimens. The males are all 5 mm. long, all have 7 pale pronotal lines, all have 5 strigil combs. Taking the right pala and the proximal peg row first in each case, the pala pegs number, 20 6–21 6, 22 6–23 5, 23 5–22 6, 20 6–22 6. The lengths of the seg-

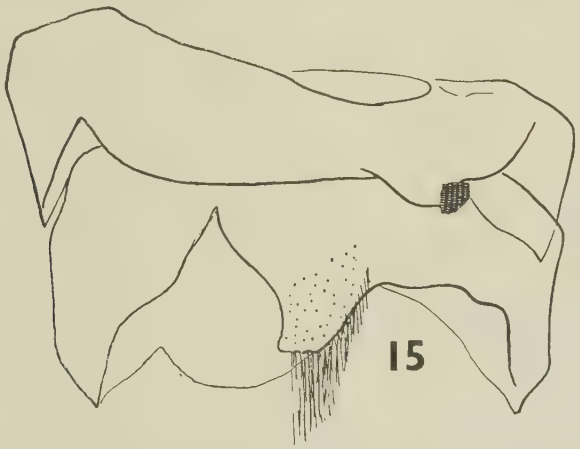


Fig. 15.—Male abdominal segments, 6th and 7th, of *Corixa semistriata* from Barra. Chaetotaxy omitted.

ments of the middle legs of three specimens are : claws 25, 26, 27, tarsi 19, 20, 20, tibiae 26, 26, 27. Male abdominal segments and lesser parameres as figs. 15, and 17, *g*, *h*. South Uist : August 1938, 1 female; North Uist : July 1938, 1 male and 2 females; Monachs : July 1938, 1 female.

Corixa semistriata has previously been recorded only from Barra (5).

Corixa (*Retrocorixa*) *limitata* Fieber.

Previously recorded from one pool on the island of Raasay by Prof. Heslop Harrison (4).

Corixa (*Subsigara*) *scotti* Fieber.

This is the most abundant and widespread of the Hebridean water bugs. Two hundred and eighty-five specimens were found in the collections, of which 141 are males and 144 females. For August the figures for the Inner Hebrides show an 11·9% excess of females and in July in the Outer group an excess of 6·9% of females, rising to 13% in August. *C. scotti* constitutes 43% of the total Corixids in the collections from the Inner Hebrides and 23% in the Outer Hebrides. The 6 islands visited and from which the species was not

collected are : Sandray, the Monachs, Berneray, Taransay, Canna and Sanday. It has previously been collected on Gigha (7), Islay (7), Jura (7), Mull (7), Rona (4), Benbecula (27) and Scalpay (4), all of which are additions to the above list, and from Raasay (4), Barra (5), South Uist (6), Harris (2, 3), and the Shetlands, a total of 27 Hebridean islands. The specimens are distributed as follows.

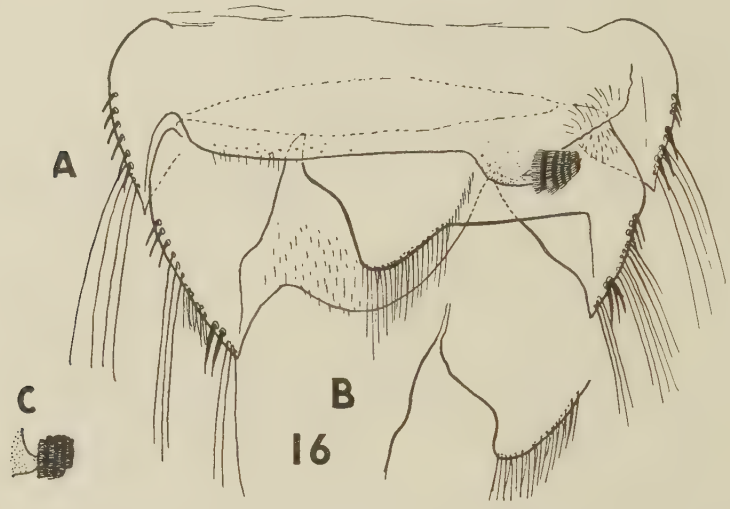


Fig. 16.—*a*, 6th and 7th male abdominal segments of *Corixa scotti* from Tiree; *b*, lobe of 7th abdominal segment of male *C. scotti* from Harris; *c*, strigil of male *C. scotti* from Harris.

Inner Hebrides :—Tiree : September 1935, 6 males and 6 females. These males measure 4·5–5 mm. long, and the colour and markings are typical. The pronotal lines number 5, 5, 6, 6, 6, 6. Strigil combs number 5, 5, 5, 5 plus a tiny comb, 6, 6. The pegs on the palae are for the right palae 27, 24, 26, 27, and for the left palae 25, 24, 28, 27 in four specimens. The lengths

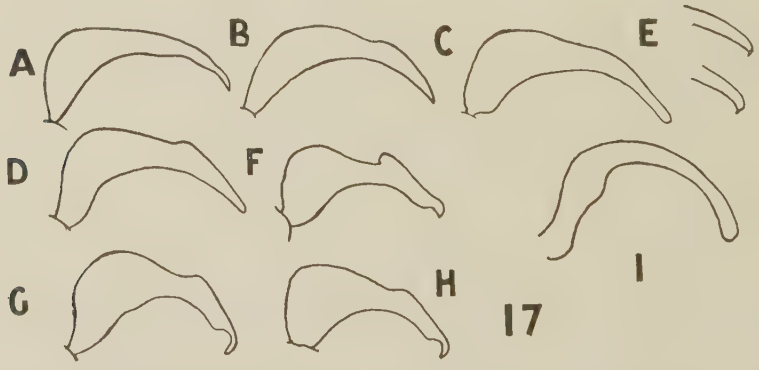


Fig. 17.—Lesser parameres of : *Corixa scotti* from *a*, North Uist; *b*, Tiree; *c*, North Uist; *d*, Harris; *e* (apex only), from North Uist; *f*, *C. venusta* from Harris; *g*, *h*, *C. semistriata* from Barra; *i*, *C. sahlbergi* from North Uist.

of the segments of the middle legs in two specimens are : claw 19, 20; tarsus 9, 9; tibia 18, 20. The abdominal segments are shown in fig. 16, *a*, and the lesser paramere in fig. 17, *b*. Coll : May 1937, 3 males and 3 females. One of these females is peculiar in that though not teneral the markings are very faint and in addition there is a lateral marginal corio-membranal spot of dark pigment on each hemielytron; July 1937, 10 males and 2 females; Muck : May 1935, 19 males and 13 females; July 1939, 1 female; Eigg : August 1936, 3 males; July 1937, 15 males and 10 females. Two specimens are teneral and 3 males have only 5 pale pronotal lines. Rhum : July 1937, 4 males and 2 females. Pronotal lines in the males number 4, 5, 5, 6, and in the females 6, 6. These specimens are rather on the dark side; August 1937, 1 male and 1 female; August 1938, 1 male; Hyskeir : August 1938, 1 male and 1 female; Soay : August 1937, a typical series of 22 males and 23 females; Raasay : August 1937, 2 females; Handa : August 1937, 7 males and 2 females. All the males have 5 pale pronotal lines.

Outer Hebrides :—Mingulay : July 1937, 1 male and 4 females; Pabbay (Barra) : July 1939, 2 females; Vatersay : July 1939, 2 males and 2 females; Barra : September 1935, 2 males and 2 females; August 1939, 5 males and 9 females; Eriskay : August 1938, 1 male and 1 female; South Uist : August 1938, 2 males and 6 females; August 1939, 1 female; North Uist : July 1938, 18 males and 15 females. These males vary in length from 4·5 to 5 mm. The colour and markings are typical but some have slightly infuscated legs. One specimen has only 4 pale pronotal lines, 9 have 5 lines, 3 have 5 clear lines and the suspicion of a sixth and 2 have 6 lines. Of those examined 4 have 5 strigil combs and 4 have 6 combs. Taking the right pala first in each case, the pegs vary over the following range : 21, obscured by dirt; 23, 27; 24, 27; 24, 25; 25, 24; 25, 25; 26, 24; 26, 24; 26, 24; 27, 25; 27, 26; 28, 26; 28, 28. The lengths of the segments of the middle leg in 5 specimens are : claws 25, 25, 28, 28, 29, tarsus 18, 18, 19, 20, 20, tibia 25, 26, 26, 28, 29. In one male the pegs of the palae are arranged in a unique manner, for they lean towards one another in pairs with their apices either touching or nearly so (fig. 17, *a*, *c*, *e*). Baleshare : April 1938, 7 males and 2 females. These specimens are on the dark side of normality. One male has 4 pronotal pale lines and one has 5. Pabbay (Harris) : July 1939, 3 males and 1 female; Harris : July 1938, 9 males and 17 females; July 1936, 1 male and 2 females. The females of the 1938 collection all measure 5·5 mm. in length and all have 6 pale pronotal lines. The breadth of these pronota varies in twenty-fifths of a millimetre from 37 to 41 and the length from 17 to 25. Both females and males are quite typical in appearance. The males vary from 4·5 to 5 mm. in length. Seven have 5 pale pronotal lines and 2 show a suspicion of a sixth, the rest have 6 lines. One has 4 strigil (fig. 16, *c*) combs and the remainder 5 combs. In 7 specimens examined the right pala has 24, 24, 26, 27, 28, 28, 29 pegs and the left pala 24, 26, 27, 25, 25, 28 and 29 pegs. The lobe of the seventh tergite is shown in fig. 16, *b*, and the lesser paramere in fig. 17, *d*. Lewis (Valtos) : July 1939, 2 females; Berneray : July 1939, 1 male and 3 females.

Corixa (*Subsigara*) *fossarum* Leach.

Previously recorded from Gigha (7), Islay (7), Raasay (16, 4) and Harris (2).

Corixa prominula Thomson.

This doubtful species has been recorded from Harris by Douglas and is quoted by Saunders who, after he had examined the original specimens, stated that it came between *C. scotti* and *C. fossarum*. However, Prof. O. Lundblad of Sweden has examined Thomson's types and come to the conclusion that these are typical examples of *Corixa scotti*, so that whatever Douglas' specimens from Harris may have been they cannot correctly be called *C. prominula*. Certainly none of the 285 Hebridean specimens of *C. scotti* from the present collections belongs to this mythical species. The only specimen I have seen which might be the "*prominula*" of Douglas and Saunders is a female that I collected in a small brackish pool near Dale in Pembrokeshire (26) which, while being more like *C. scotti* than any other known British species, is not quite like any *C. scotti* I have seen as far as markings are concerned.

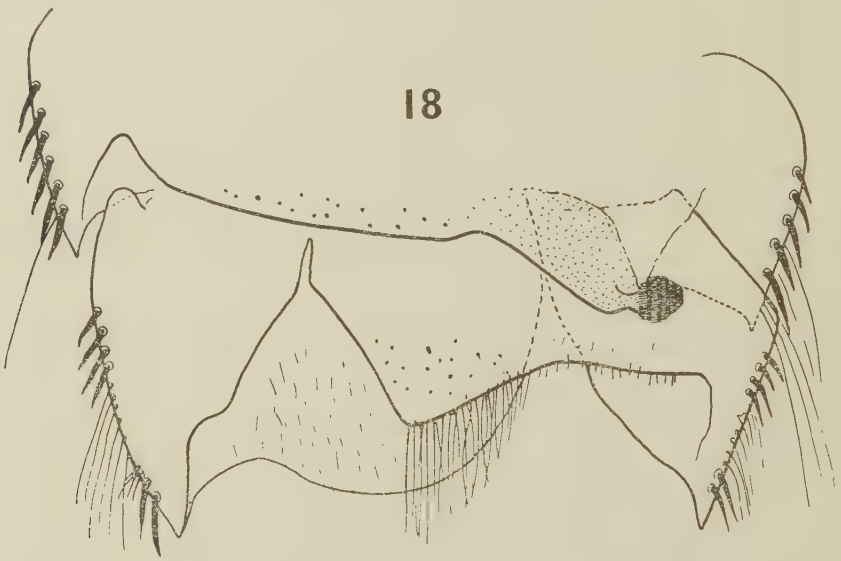


Fig. 18.—Sixth and seventh male abdominal segments of *Corixa distincta* from Harris.

Corixa (*Subsigara*) *falleni* Fieber.

One male was found in the collections from Eigg, May 1938. Apart from this solitary specimen there are no other Hebridean records. It is rare in Scotland and uncommon in the north of England.

Corixa (*Subsigara*) *distincta* Fieber.

115 specimens were found in the collections and 49 were males.

Inner Hebrides :—Coll : May 1937, 1 male and 3 females; July 1937, 9 males and 3 females; Muck : May 1938, 2 males and 2 females; 1937 (?), 4 males; Eigg : August 1936, 3 males and 2 females. These males measure 7–7·5 mm. in length and are typical in markings and colour. One male has 8 pale pronotal lines and the remainder have a suspicion of a ninth. All have 6 strigil combs. The pala pegs where they could be counted are, in the basal row 13, 14, 14, and in the apical row 13, 16 and 20. The extremes of the

measurements of the segments of the middle legs are : claw 36, tarsus 30, 33, tibia 42, 45. Genitalia typical; July 1937, 5 males and 4 females; Rhum : July 1937, 5 females, 4 have 8 pale pronotal lines and one has 9; August 1938, 1 male; Hyskeir : August 1938, 1 male; Soay : August 1937, 4 males and 3 females. Two males have 6 strigil combs and one has 7 combs. Pala pegs in the right proximal row 14, 12, 13, in the right apical row 18, 21, 15, and in the left proximal row 12, 14, 13, in the left apical row 16, 20, 19.

Outer Hebrides :—Mingulay : July 1937, 1 male; Sandray : July 1939, 1 female; Barra : September 1935, 3 males and 1 female; South Uist : August 1938, 4 males and 14 females; North Uist : July 1938, 5 males and 12 females. Four males have 8 pale pronotal lines and one has 9. One has a strigil with only 5 combs. Pala pegs in 3 specimens are 13, 14; 15, 10; 19, 14; 20, 14; 15, 12; 14, 14, the right pala and proximal row being taken in each case; Baleshare : April 1938, 2 males and 10 females. These are dark specimens with infuscated legs. Pronotal lines vary from 7 to 8; Harris : July 1938, 1 male and 4 females. This male is 7 mm. long, has 7 pale pronotal lines and is rather dark in colour. Pegs on the right pala are 21, 13 and 22, 15 on the left (fig. 18). *C. distincta* has previously been recorded from Gigha (7), Islay (7), Jura (7), Raasay (4), Harris (2), and Benbecula (27), which raises the number of occupied islands to 18.

Corixa (*Arctocorixa*) *germari* Fieber.

Only 7 specimens were discovered in the collections, but it has previously been recorded from Islay (7), Jura (7), Barra (5), and Harris (2).

Outer Hebrides :—Barra : August 1939, 1 male 8 mm. long, which is unusually dark in colour and has 10 pale pronotal lines, 36 pegs on each pala, 18 combs in the strigil. The lengths of the segments of the middle legs are : claws 33, tarsi 27, tibiae 40. Head and legs a little infuscated, and pronotal keel very prominent on the anterior half. Abdominal segments and genitalia as fig. 19, *a*, *b*, *c*, *d*. Eriskay : August 1938, 1 male 7 mm. long. This is just as pale as the specimen from Barra is dark. Monachs : July 1938, 1 female; Harris : July 1938, 1 male; Taransay : July 1938, 1 male and 2 females. The females are 7·5 mm. long, and there are about 8 pale pronotal lines. The lengths of the segments of the middle legs are : claws 29, tarsi 27, tibiae 39. The male is 7 mm. long and is quite pale in colour. There are 10 pale pronotal lines. The right pala has 32 pegs and the left 34. The lengths of the segments of the middle legs are : claws 32, tarsi 27, tibiae 40.

Corixa (*Arctocorixa*) *carinata* Sahlberg.

This species is represented by only 4 females. It has previously been recorded from Islay (7), Jura (7), S. Uist (6), Benbecula (27), and also from the Shetlands.

South Uist : August 1938, 1 female; Eriskay : August 1938, 1 female, 8·5 mm. long, pale in colour and with a well-developed pronotal carina. Length of middle tarsus 32, tibia 45; Taransay : July 1938, 1 female 9 mm. long; Baleshare : April 1938, 1 female, 8·5 mm. long and dark in colour. Pronotal keel, for which character the species received its name, very poorly developed. Lengths of the segments of the middle leg are : claws 35, tarsi 34, tibiae 47.

Identification of females of this species is not easy, since colour is no guide, but the middle leg segments appear to be quite helpful.

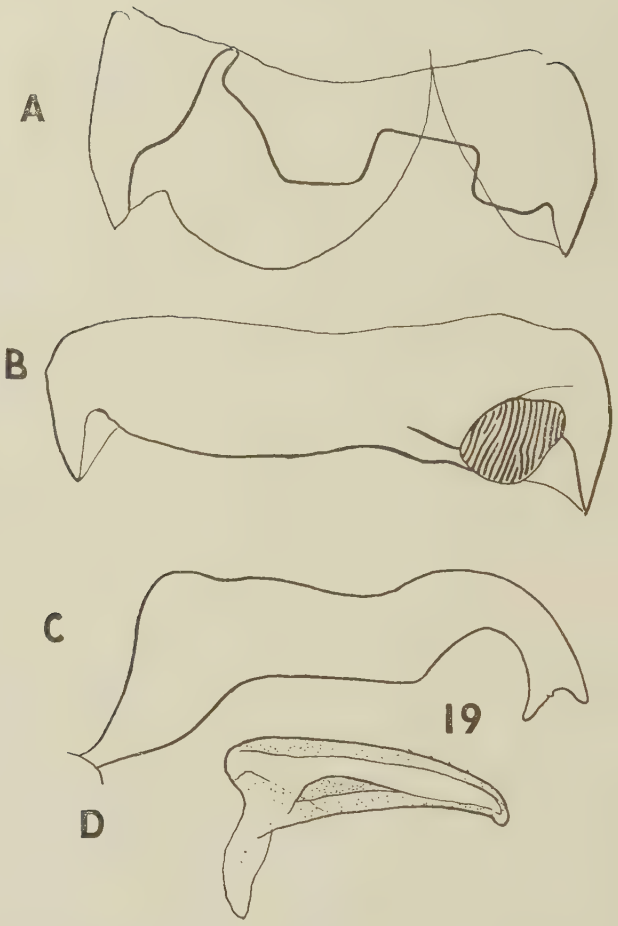


Fig. 19.—*Corixa germari* from Barra. *a*, 7th abdominal segment; *b*, 6th abdominal segment; *c*, lesser paramere; *d*, greater paramere, about $\frac{1}{3}$ the scale of the lesser paramere.

Corixa (*Anticorixa*) *castanea* Thomson.

This insect has now been collected on 20 Hebridean islands. It is represented in the present collections by 120 specimens, of which 39 are males, and has been previously recorded from Islay (7), Iona (1), Canna (5), Sanday (5), Raasay (4), Rona (4) and Benbecula (27). The series as a whole is quite typical and what slight variation is found in the lesser parameres is illustrated in fig. 20.

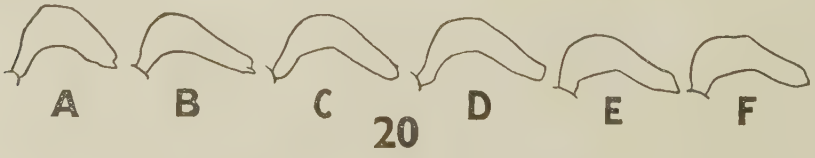


Fig. 20.—Lesser parameres of *Corixa castanea* from *a*, Harris and *b–f*, Barra.

Inner Hebrides :—Tiree : September 1935, 6 males and 7 females; Muck : May 1938, 1 male and 3 females; 1937, 2 females; July 1939, 1 female; Eigg : May 1938, 3 females; Hyskeir : August 1938, 1 female.

Outer Hebrides :—Mingulay : July 1937, 1 male; Barra : August 1939, 10 males and 24 females. These males are 4·5 mm. long and all have 6 pale pronotal lines. The strigil combs 3 in one, 3 and a tiny extra comb in 4 specimens, and 4 combs in the remainder. The number of pegs in the right palae are 19, 19, 18, 17, 19, 17, and in the left 17, 18, 18, 18, 19, 16. The variation in the shape of the lesser parameres as fig. 20, *b*, *c*, *d*, *e*, *f*. Eriskay : August 1938, 1 female; South Uist : August 1938, 10 males and 9 females; August 1938, 5 males and 9 females; North Uist : July 1938, 8 males and 7 females; Berneray : July 1939, 1 female; Pabbay (Harris) : July 1939, 1 female;

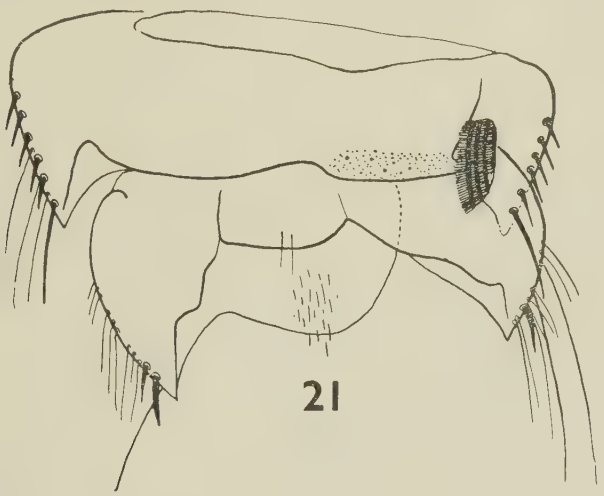


Fig. 21.—6th and 7th abdominal segments of a male *Corixa castanea* from Harris.

Harris : July 1938, 2 males and 3 females. These males are 4·75 mm. long, have 6 pale pronotal lines and 4 combs in the strigil. Pala pegs are 18, 17, 18, 18. Abdominal segments as fig. 21. Lesser parameres as fig. 20, *a*; Taransay : July 1938, 3 females.

C. castanea has also been previously recorded from Barra (5).

Corixa (*Anticorixa*) *moesta* Fieber.

This has been recorded from a number of Hebridean islands, but these records were made before it was known that *Corixa castanea* was a British species (1). No specimens of *C. moesta* were found in the collections now under consideration, and it is most improbable that any of the previous records refer to this species; all should refer to *C. castanea*.

Corixa (*Anticorixa*) *linnei* Fieber.

This is a rare species in the Hebrides and has been previously recorded only from Gigha (7) and Barra (*A. R. Waterston*). Only three specimens were found in these collections : they are typical.

Tiree : September 1935, 1 female; Muck : July 1939, 1 male; Eigg : May 1938, 1 female.

Corixa (*Anticorixa*) *sahlbergi* Fieber.

Remarkably few specimens were found in the present collections, but it has been previously recorded from Gigha (7), Islay (7), Jura (7), Mull (7), Sanday (10), Raasay (4), Rona (4), Scalpay (4), Barra (5), and Harris (2).

Eigg : May 1938, 2 females; South Uist : August 1938, 1 female; Monachs : July 1938, 1 female; Berneray : July 1939, 1 female; North Uist : July 1938, 2 males and 6 females. These are typical in shape, markings, and colour, the legs being strongly infuscated. One male is 7 mm. long, the pronotum has 8 paler pronotal lines, and the strigil has 6 well-developed and one poorly developed comb. Both palae have 21 pegs and the lengths of the segments of the middle leg are : claw 27, tarsi 30 and tibiae 30. The shape of the paramere is as fig. 17, *i*. Abdominal segments as fig. 22.

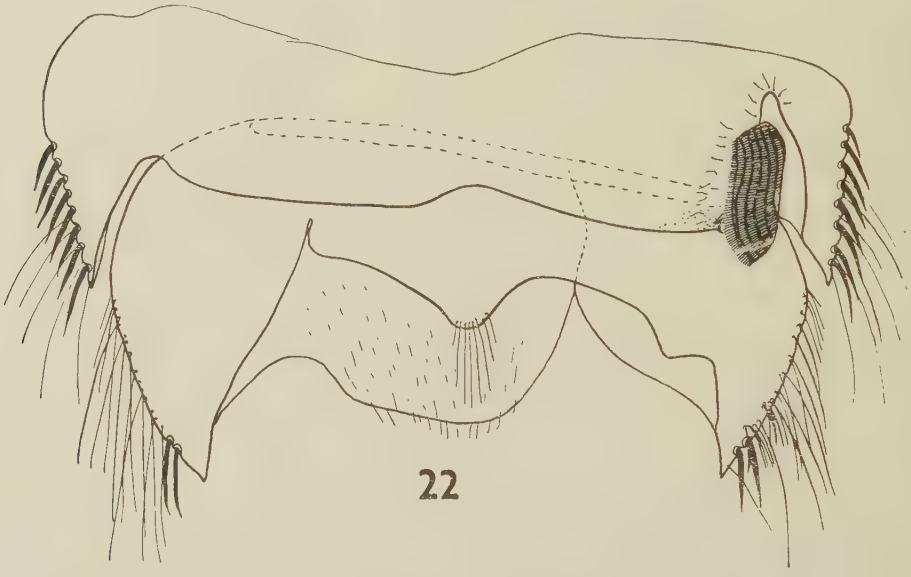


Fig. 22.—Sixth and seventh male abdominal segments of *Corixa sahlbergi* from North Uist.

Corixa (*Corixa*) *punctata* Illiger (= *geoffroyi* Leach).

Most of the following records refer to larvae, which can be identified by their large size, and distinguished, at least in the last three instars, from the larvae of *Corixa dentipes* by the lack of the characteristic shape of the middle femero-tibial joint.

Inner Hebrides :—Coll : July 1937, 1 male 12 mm. long; May 1937, 1 male 11 mm. long and 4 females 11–12 mm. long; Muck : July 1939, 4 males and 3 females; Eigg : July 1937, 1 female; August 1936, 1 male 10·5 mm. long with 9 strigil combs, 16 pale pronotal lines, 28 pegs on each pala and abdominal segments as fig. 23; Rhum : August 1938, 1 female; Soay : August 1937, 1 nymph; Handa : August 1937, 1 male 10·5 mm. long, with 14 pale pronotal lines, 8 strigil combs, 27 pegs on each pala and abdominal segments identical with those of the male from Eigg.

Outer Hebrides :—Vatersay : July 1939, 1 fifth-instar nymph; Barra :

August 1939, 1 third-instar nymph, 2 fourth-instar nymphs and 1 fifth-instar nymph; Berneray: July 1939, 1 female; Pabbay (Harris): July 1939, 1 fifth-instar nymph; Harris: July 1938, 1 female; Berneray: July 1939, 1 nymph.

Corixa punctata has been previously recorded from Gigha (7), Islay (7), Jura (7), Raasay (4), Rona (4), and Barra (5).

Corixa (*Corixa*) *dentipes* Thomson.

One typical female specimen measuring 12·5 mm. was found in the collections from Eriskay, August 1938. This is the only record for the whole Hebridean group.

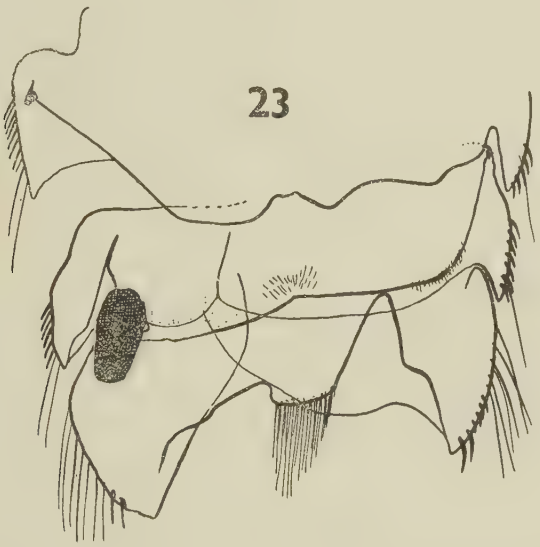


Fig. 23.—5th, 6th and 7th abdominal segments of a male of *Corixa punctata* from Eigg.

Corixa (*Corixa*) *panzeri* Fieber.

The discovery of this species in the collections came as some surprise, but unfortunately no males have yet been found to permit critical comparison with southern material.

Monachs: July 1938, 2 females; Taransay: July 1938, 1 female and 1 fifth-instar nymph.

The only previous record is of a pair of hemielytra found in a pond on the island of Canna by W. H. R. Lumsden of the Glasgow University Canna Expeditions 1936 and 1937 (10).

Corixa (*Sigara*) *striata* L.

The collections contain 64 specimens of this species, 31 of which are males.

Inner Hebrides:—Coll: May 1937, 2 males and 3 females; Rhum: August 1937, 5 males and 11 females; Raasay: August 1937, 1 male and 5 females.

Outer Hebrides:—South Uist: August 1938, 5 females; North Uist: July 1938, 7 males and 8 females; Monachs: July 1938, 1 male; Pabbay (Harris):

July 1939, 1 male; Harris: July 1938, 2 males; July 1936, 6 males and 6 females. This series is quite typical in appearance, the females are 7 mm. long, and the males 6·5–7 mm. long, all have 6 pronotal lines. Five of them have 9 strigil combs and one has 10. The pala pegs vary as follows, taking the right pala and the basal row first in each case: 15 20– 12 20, 13 19–13 19,

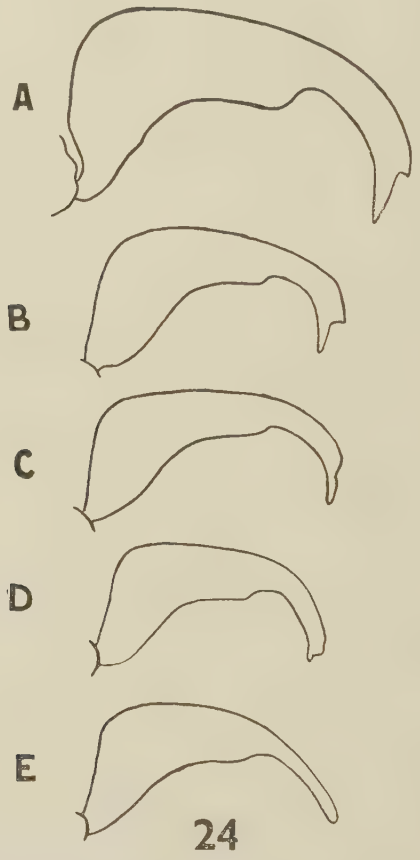


Fig. 24.—Lesser parameres in *Corixa striata*. *a*, normal example from Taransay; *b–d*, variations in specimens from Harris; *e*, abnormality from Harris.

13 19–10 19, 17 20–13 21, 13 19–13 20, 12 21–12 20. The lengths of the segments of the middle leg are: claw 24, 24, 26, 26, 28, tarsus 25, 27, 25, 29, 26, tibia 34, 37, 34, 32, 37. The abdominal segments as fig. 11, *f*. Variation of the lesser paramere as fig. 24, *b–e*. Lewis (Valtos): July 1939, 1 larva; Taransay: July 1938, 1 male, fig. 24, *a*, fig. 11, *f*.

Corixa striata has previously been recorded from Islay (7), Jura (7), Raasay (4), Rona (4), Barra (5), and Harris (2).

II. DISCUSSION.

It will be convenient first to consider the aquatic Hemipterous fauna of the Hebrides as a whole, dividing the species into a number of categories and then to compare the fauna of the Inner Hebrides with that of the Outer Hebrides.

Category 1.—Species expected to be common in the Hebrides, and found to be so.

Velia currens Fabricius is an ubiquitous species and is able to breed at a low temperature. The relative absence of dust in the air is probably the factor which allows it to inhabit stagnant water in the Hebrides. In the south dust particles prevent it from skimming over the surface of such habitats.

Gerris costai Herrich-Schaeffer. Evidence is accumulating to support the view put forward by Prof. Poisson of Rennes that *G. costai* and *G. thoracica* are possibly only forms of the same species. Poisson believes *G. thoracica* to be a mutation of *G. costai*; does the Hebridean distribution support this view? In the British Isles *G. costai* is a subalpine species, becoming rare south of the Scottish border and uncommon in northern Ireland. In the Hebrides it occurs at all altitudes, even on brackish pools. Does the low mean summer temperature favour this species or inhibit the others, enabling *G. costai* to compete with them?

Salda littoralis L. It would be expected that this frequenter of marine swamps would be the commonest species in the Hebrides considering the great length of available coastline.

Notonecta obliqua Gallén was found to be strikingly more abundant than *N. glauca*, the ecological requirements of which are very little different.

I have shown in a paper on the oviposition of the British species of *Notonecta* (24) that the ovipositing habits are in large measure responsible for the type of habitat frequented, but in the Hebrides it is probably the low mean summer temperature which prevents *N. maculata* and *N. viridis* from occurring, and this is probably also true of *N. glauca*. It may be noticed by collectors that, although *N. obliqua* is often quite abundant in the south and west, it is usual to take it in pools on hills, and these, even if of such low altitudes as 600 ft., appear to give *N. obliqua* a distinct advantage over *N. glauca*. Judging by the frequency with which *N. viridis* is taken in coastal districts, especially Cornwall and Pembrokeshire, where it is dominant and where I have collected it on Skokholm Island, the Hebrides would appear to be ideal were it not for the temperature bar.

Cymatia bonsdorffi Sahlberg. Macan (21) has shown that this insect is most abundant in tarns, where it replaces *Corixa scotti* and *C. distincta* when the proportion of accumulated organic matter in the substrata becomes higher. The frequence of tarns in the Hebrides no doubt accounts for the abundance of this species, and the high proportion of macropterous specimens is possibly another important factor favouring its dissemination.

Corixa praeusta Fieber, *Corixa punctata* Illiger, *Corixa nigrolineata* and *Corixa striata* L. form a group of ubiquitous species all inhabiting a wide variety of habitats. *C. striata* finds its optimum conditions in lakes, which accounts for its being the fourth most abundant Corixid species in the Hebrides.

Corixa wollastoni Douglas & Scott is undoubtedly favoured by the low

mean summer temperature, like *Gerris costai*. It is the eighth most frequently taken Hebridean Corixid species.

Corixa scotti Fieber was found to be twice as abundant as any other Hebridean Corixid species. It favours acid waters, particularly if peaty, and occurs in those parts of the habitat where the percentage of organic matter in the substrata is relatively low and where there is little growing aquatic vegetation. Roughly speaking, the farther north and west one collects the more abundant does *C. scotti* become. Thus the Hebridean islands with their moorland nature form the ideal country for such a species, and it is recorded from 27 of the 35 islands from which collections of water bugs have been made.

Corixa distincta Fieber is found throughout the British Isles, inhabiting pools of all kinds and slowly running waters, but its optimum requirements appear to be slightly acid lakes and tarns where the percentage organic matter in the substrata (according to Macan (21)) is relatively low, lower than the value for *C. scotti*. It is for this reason that in the Hebrides *C. distincta* is the third most abundant species.

The second most abundant Corixid species in the Hebrides was found to be *Corixa castanea* Thomson. It is found only in acid waters especially where *Sphagnum* grows, both moorland pools and sluggish peaty moorland streams, wherever these occur.

Corixa venusta Douglas & Scott is never an abundant species in the south, but appears to become distinctly commoner farther north. It occurs throughout the British Isles in rapidly running shaded streams and also in certain moorland pools.

Category 2.—Species uniformly uncommon, but to be expected in the Hebrides, where they are also uncommon.

These are *Gerris lateralis* Schummel, *Glaenocorixa cavifrons* Thomson, *Corixa wollastoni caledonica* Kirkaldy, *C. semistriata* Fieber, *C. germari* Fieber, *C. carinata* Sahlberg, *C. dentipes* Thomson, *Salda morio* Zetterstedt, *Saldula scotica* Curtis and *Cryptostemma alienum* Herrich-Schaeffer. All these species are very local and should be looked for in special places; for example, *Cryptostemma alienum* lives at the water's edge on large shingle banks by the sides of rivers, and *Gerris lateralis*, unlike the other water skaters, in thick vegetation.

Category 3.—Species common and widely distributed, but rare in the Hebrides.

Almost without exception these species become rarer farther northwards, and the most probable factor restricting them is the low mean summer temperature as well as in some instances a lack of suitable habitats. These species are *Gerris lacustris* L., *G. thoracica* Schummel, *G. odontogaster* Zetterstedt, *Saldula pallipes* Fabricius, *S. saltatoria* L., *Nepa cinerea* L., *Notonecta glauca* L., *Micronecta poweri* Douglas & Scott, *Corixa lateralis* Leach, *C. fossarum* Leach, *C. limitata* Fieber, *C. falleni* Fieber, *C. sahlbergi* Fieber, *C. linnei* Fieber.

Category 4.—Species unexpected in the Hebrides, but present in small numbers.

These are *Cymatia coleoptrata insularis* subsp. n., *Micronecta minutissima* L. and *Corixa panzeri* Fieber. The last is not uncommon in alkaline and calci-

phile habitats in England, while in Ireland Halbert (25) says it is probably widely distributed. In northern England it is quite uncommon and in Scotland must be very rare. For this reason the Hebridean records are very interesting, especially the occurrence in the Monach islands.

It is worth listing the species of another category, namely :—

Category 5.—Species common throughout the greater part of the British Isles but not yet recorded in the Hebrides.

These species are *Microvelia reticulata* Burmeister, *Hydrometra stagnorum* L., *Gerris argentata* Schummel, *G. gibbifera* Schummel, *G. najas* De Geer, *Saldula c-album* Fieber, *S. pilosella* Thomson, *Halosalda lateralis* Fallen, *Chartoscirta cincta* Herrich-Schaeffer, *Plea minutissima* Fuessly, *Aphelochirus aestivalis* Fabricius, *Notonecta maculata* Fabricius, *N. viridis* Delcourt, *Naucoris cimicoides* L., *Ranatra linearis* L., *Micronecta scholtzi* Fieber, *Corixa concinna* Fieber, *C. moesta* Fieber, *C. stagnalis* Leach, *C. affinis* Leach, *Hebrus ruficeps* Thomson, *Mesovelia furcata* Mulsant & Rey, *Saldula orthochila* Fieber, *Chartoscirta cocksii* Curtis. Some of these species may yet be taken in the Hebrides but they must of necessity be very rare; most of them are really southern forms and six of them are absent from Ireland so that they are possibly species which are newcomers in the south, or which are prevented from spreading northwards, or have been driven southwards by the temperature differences.

Category 6.—Includes a number of species everywhere rare, to be expected in the Hebrides but not yet found there.

These species are *Gerris rufoscutellatus* Latreille, *Salda oculata* Muller, *Saldula opacula* Zetterstedt, *S. riparia* Fallen, *Chartoscirta elegantula* Fallen, *Pachycoleus rufescens* Sahlberg. This leaves fifteen species which will probably not be found in the Hebrides.

On considering the Hebrides as a whole it will be seen that 41 species and subspecies of aquatic Hemiptera have been recorded at one time or another, and these constitute just half of the total number of species known to be British, now numbering 84. If this total is divided into its respective ecological groups, there are 21 species which live at the margin of the water, 20 living upon the surface of the water and 43 subaquatic forms, of which 34 are Corixidae, and on comparing the Hebrides with a comparable area in the south of England, for example Hampshire and Dorset, it may be seen that there is an absolute reduction in the number of all species other than the Corixidae, see Table 1.

Table 1.

% representation of aquatic Hemiptera species in the Hebrides compared with Hants and Dorset.

Region	Marginal spp.	Surface spp.	Subaquatic	Corixidae	Temperature: Jan.	July
Hants & Dorset	66	65	100	76	40° F.	62° F.
Hebrides	28	30	33	76	42° F.	55° F.

From Table 1 I conclude that the Corixidae are less affected by the temperature than the other families of aquatic Hemiptera, since although there is a definite subalpine element present, this is not great enough to account for the whole similitude.

As to the zoo-geographical aspect of the Hebridean species, only one species can definitely be placed in the south-eastern element, and that is *Cymatia coleoptrata*, represented, however, by a subspecies. *Corixa panzeri* can be described as definitely southern, its range including Spain and Palestine. *Corixa falleni* and *C. lateralis* are also southern, but they have a somewhat wider range in Britain. The greater portion of the remaining species are ubiquitous in Europe and the British Isles but several, like *Corixa distincta*, *C. venusta* and *C. semistriata*, become gradually more abundant towards the north. The subalpine element is represented by *Corixa wollastoni* and its subspecies *caledonica*, *C. carinata*, *Glaenocorixa cavifrons*, *Gerris costai* and *Salda morio*, while *Corixa scotti*, *C. castanea*, *C. germari*, *Notonecta obliqua*, *Gerris lateralis* and *Saldula scotica* are north-western in their distribution.

Since there are now available ample statistics for comparing the Corixid populations of several areas in Great Britain I append in Table 2 figures of

Table 2.

% abundance of the Corixidae compared with three other areas.

Species	Region			
	Hebrides	Lake District	Studland Dorset	Somerset
C. scotti	**33**	**29**	**30**	4·5
C. castanea	**14**	**8·5**	**17·5**	2·5
C. distincta	**13**	**11·5**	1	1
C. striata	**7·5**	**17·5**	1	**7**
C. praeusta	**7**	2·5	**7**	1
Cy. bonsdorffi	**6**	**7**	**17·5**	1
C. wollastoni	5	1	0	0
C. nigrolineata	5	1	1	**7**
C. venusta	4	1	1	1
C. semistriata	3	0	0	1
C. punctata	2	1	1	**7**
C. sahlbergi	1·5	1	3	2·5
C. falleni	1	1	0	**30**
C. lateralis	1	1	1	**7**
C. fossarum	1	**12·5**	0	2·5
C. limitata	1	0	0	1
C. linnei	1	4	**7**	1
Cy. coleoptrata	1	0	**15**	1
M. poweri	1	**6**	0	1

the numerical abundance of Corixid species as a percentage of the total collections from several areas for comparison with similar figures for the Hebrides taken as a whole. These areas are: first, the Lake District, studied by Macan (21) and for the purpose of this paper represented by 3700 specimens. Secondly South Haven Peninsula, Studland Heath, Dorset, an area no larger than many of the smallest Hebridean islands, but rich in a wide variety of habitats and with soft acid water. This area was studied largely by Macan, C. J. Banks and myself (23) and is represented by 2040 specimens. The third area is north Somerset, and is based on unpublished figures obtained

by myself totalling 9050 specimens. Somerset is an area of chiefly hard alkaline waters. It is not necessary to enlarge upon this table since it is self-explanatory, except to point out that in each area the dominant species reaches 30% of the total, and that in the first three regions, which are acid, *Corixa scotti* is dominant while in north Somerset with an average *p*H value of the water of 8, *Corixa falleni* is dominant. Those species which form over 5% of the total population are marked in heavy type, since this is the figure given if all the species were equally abundant. Species forming less than 1% of the total are considered as 1%.

A comparison of the aquatic Hemipterous fauna of the Inner and Outer Hebridean islands.

Since the figures are not really large enough for an accurate comparison in most cases, it will suffice to say that the Saldidae, Veliidae, Gerridae, Nepidae and Notonectidae appear to be roughly evenly distributed between the two groups of islands. *Notonecta glauca*, which is such a common species everywhere, has been taken only on Barra in the Outer Hebrides; it should be emphasised that it is not easily overlooked. Table 3 shows the % abun-

Table 3.

% abundance of Corixidae in the Inner and Outer Hebrides compared with the number of islands occupied.

	% abundance of species		No. of islands occupied	
	Inner Hebrides	Outer Hebrides	Inner Hebrides	Outer Hebrides
C. scotti	43	23	15	12
C. distincta	14	12	10	7
C. praeusta	12·5	1·5	10	1
Cy. bonsdorffi	10	3	12	3
C. semistriata	2	1	3	5
C. castanea	5	15	10	9
C. striata	4	8·7	6	8
C. nigrolineata	0·25	8	6	8
C. venusta	—	6·5	8	7
C. wollastoni	—	10	4	4

dance of the 10 most common Corixid species in the Inner and Outer Hebrides compared with the number of islands in which they have been collected. It will be seen that only in the case of *Cymatia bonsdorffi*, *Corixa praeusta*, *C. distincta* and *C. scotti* do the figures of the % abundance agree with the number of occupied islands. However, it is much more probable that the figures represent the truth rather than that the methods of collecting were at variance in the two groups of islands. From the table it is safe to say that *Corixa distincta* and *C. scotti* are both equally abundant in the Inner Hebrides and the Outer Hebrides; that *Cymatia bonsdorffi* and *Corixa praeusta* are both much more abundant in the Inner Hebrides than in the Outer Hebrides and that it is possible that *Corixa castanea*, *C. striata*, *C. nigrolineata*, *C. venusta* and *C. wollastoni* are more numerous in the Outer Hebrides but occupy about the same number of islands in both groups.

Remarks on the morphology of the Hebridean aquatic Hemiptera.

It is usual for Scottish water bugs to be distinctly darker in colour than their corresponding southern representatives. The best example is afforded by the interesting case of *Glaenocorixa cavifrons* summarised by Hutchinson in his paper on the Hemiptera of Islay (7), Jura (7) and Gigha (7). This species is rare in England, where it is represented by a race of smaller pale-coloured specimens with clear markings, but in Scotland it is represented by a race of larger, more robust specimens, much darker in colour and with vaguer markings. The darkening is due in the main to a general staining of the chitin as well as to a widening of the black lines. Scottish specimens of *Gerris costai* are also frequently almost black. What few Scottish Corixidae I have been able to examine have generally been much darker than southern material.

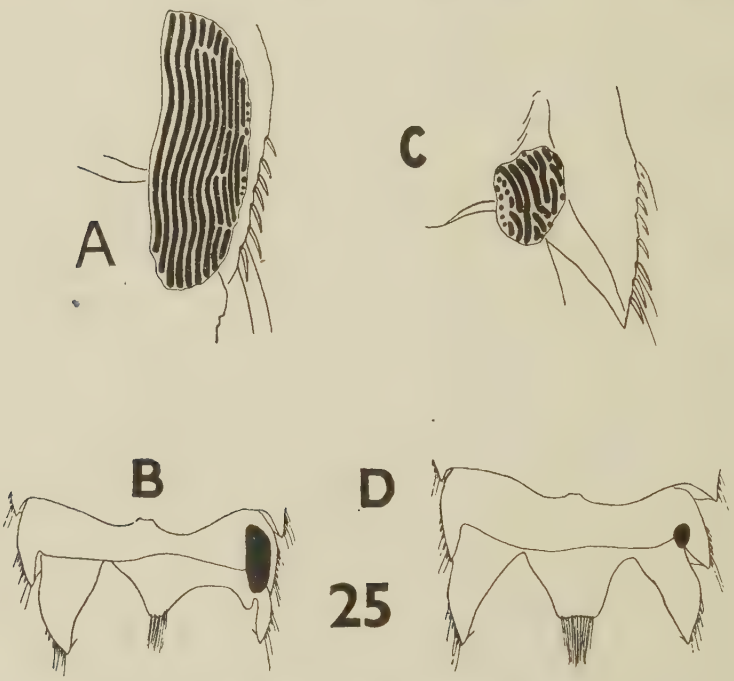
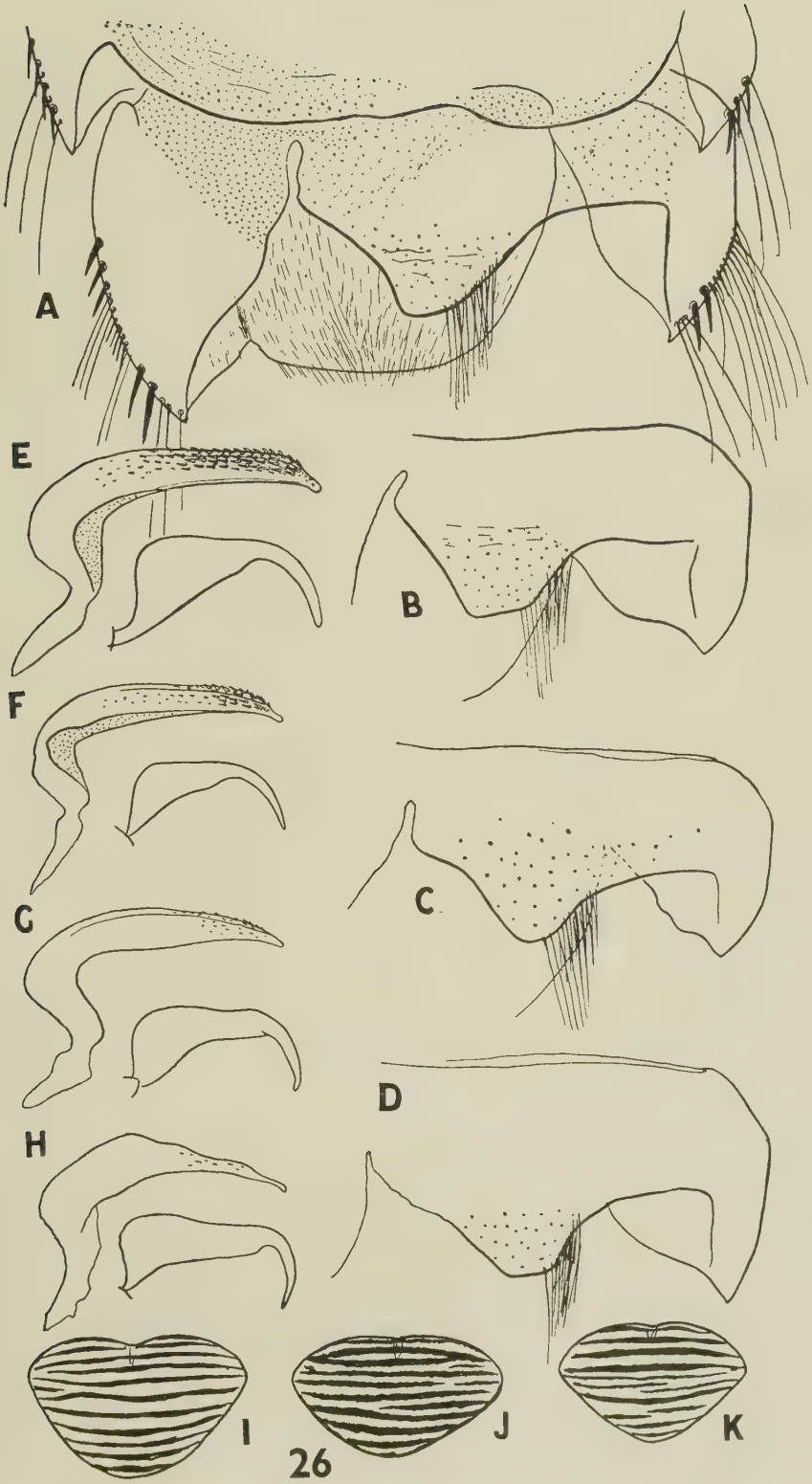


Fig. 25.—*C. striata*. *a*, *b*, normal strigil and abdominal segments; *c*, *d*, abnormal strigil and abdominal segments from Poland.

On the other hand, the material from the Hebrides is, as a general rule, not like the Scottish specimens. Indeed most of the specimens might, from their appearance, have come from almost anywhere in the south. The *Velia currens* are on the whole darker than average southern specimens. Nothing out of the ordinary is discernible among the Gerridae and Notonectidae,

Fig. 26.—Seventh male abdominal segment of *C. wollastoni* from Harris. *a*, typical specimen; *b*, from North Uist; *c*, *C. w. caledonica* from Loch Leven; *d*, *C. w. caledonica* from Handa; *e*, greater and lesser parameres of *C. wollastoni* from North Uist; *f*, *C. w. caledonica* from Handa; *g*, *C. praeusta* from Barra; *h*, *C. praeusta* from Eigg, a slight abnormality in one male; *i*, pronotum of *C. wollastoni*; *j*, pronotum of *C. praeusta*; *k*, pronotum of *C. w. caledonica*.


A
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except the inclusion of one specimen of the paler variety of *Notonecta obliqua*. Among the Corixidae only *Corixa nigrolineata* and *C. distincta* show a slight increase in the brownish tint, and a few specimens of quite a number of species show slight infuscation of the legs and the head, but only the series from Baleshare and Harris show the characteristic darkening.

Corixa scotti is interesting in that the males generally show five pale transverse lines on the pronotum instead of the usual six. Some of these males have only four, and it is interesting that Halbert (25) has reported in Ireland "as a rule there are five lines on the pronotum, and sometimes there is a faint indication of a sixth. I have also seen one or two specimens with only four clear lines, but this form must be very rare." *Corixa scotti* also shows some variation in the shape of the middle lobe of the seventh male tergite, but this is present in specimens from the same habitats. The same degree of variation in the middle lobe of the seventh male tergite is shown in *Corixa wollastoni*, and those interested are referred to the discussion under *C. wollastoni caledonica* (fig. 26). The *C. praeusta* show an interesting variation in this same part; here two distinct types of lobe appear to be met with in males from the same locality; in some it is in the form of a rough ellipse and in the others broader and transversely truncated (fig. 11, *a*, *b*, *c*, *d*, *e*). A slight variation of the parameres of *Corixa praeusta* is shown in fig. 26, *g*, *h*. One interesting variation of the genitalia of *Corixa striata* was found. In a specimen, otherwise normal in every respect, the lesser paramere was of the shape seen in *Corixa falleni*, and is obviously not a case of accidental deformity (fig. 24, *e*). I give a reproduction of another variation in this species reported by Dr. T. Jaczewski from Poland, for comparison (fig. 25). These abnormalities are not common among the Corixidae and the only others I know of are reversal of the asymmetry of the male abdominal segments in a specimen of *Corixa affinis* reported from Egypt by Jaczewski and a male of *Corixa germari* I have from Killarney which lacks a strigil, so large in this species. I also have a male of *Corixa distincta*, collected by Mr. Philip Harwood in the New Forest on 8 November, 1936, and spotted by Mr. E. C. Bedwell, in which the genitalia are quite abnormal. Specimens of *Corixa falleni* from south-eastern Europe all appear to have larger trapezoidal palae. I give figures of the slight variations found in the lesser parameres of *Corixa scotti* from the Hebrides (fig. 17, *a*–*e*).

Another interesting variation is the two-segmented condition of the one tarsus of the middle leg of the single Hebridean specimen of *Micronecta minutissima* (fig. 5). The other variation is the condition of the lesser parameres of the *Cymatia coleoptrata* (fig. 7).

I have recorded in this paper a large number of measurements of the segments of the middle legs of the Corixidae and counts of the strigil combs and pegs on the male palae in the hope that some day large collections will be made on the Scottish mainland and a comparison with the Hebridean material will be possible. At present the variations seen in these measurements appear to be paralleled by material from the south. It also appears that one is liable to discover greater variations both of colour and of structure in material collected in different ecological loci within one habitat from almost anywhere than one is likely to meet in series selected, say, from the Hebrides and Killarney or Somerset or Norfolk, for example.

The specimens studied in this paper and microscopical preparations made from 115 of them are deposited in the Hope Department at Oxford University.

III. CONCLUSIONS.

For a part of the British Isles the aquatic Hemiptera of the Hebrides is peculiar in that SALDIDAE, GERRIDAE, NEPIDAE and NOTONECTIDAE are very poorly represented as regards both numbers of species and specimens, and, moreover, many of these species are abundant in most parts of the country. Further, these species show little indication of "Scottish facies." On the other hand, the Hebrides are very rich in the number and variety of its fauna of CORIXIDAE, including several instances of isolation of southern forms. In general appearance the series resemble material from the more southern parts of the British Isles, and could be described as "typical" rather than being like the dark specimens from the same latitude in Scotland. The range of variation and the number of abnormalities found in these relatively small collections might be taken to indicate that the species of aquatic Hemiptera inhabiting the Hebrides are in an unstable state; some may be moving towards the production of subspecies, as has happened extensively in other groups of Hebridean animals. However, it must be remembered that geologically the water bugs are a very ancient group and fundamentally are morphologically relatively stable and have, to a large extent, withstood those influences upon their evolution which are at play in the Hebrides. The discontinuous distribution of some of the species present might indicate that the climate in the Hebrides has been warmer than it is now and that means formerly existed for certain species to reach the more distant islands now isolated.

ACKNOWLEDGEMENTS.

I am especially indebted to Prof. J. W. Heslop Harrison, F.R.S., for the opportunity of studying his extensive collections, and for the patient help he has given me in correspondence. I am also indebted to Mr. A. R. Waterston, Dr. T. T. Macan and to Prof. G. E. Hutchinson of Yale University, for their valuable assistance with regard to previous works on the Hebrides and records from Scotland.

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